Dear Sir:

Enclosed is a report entitled "Gonadal Dose Received in the Medical Use of X-Rays". This report is the third section of a larger report entitled "Genetic Radiation Dose Received by the Population of the United States" which is being prepared for the use of the Genetics Committee of the National Academy of Science's study of the Biological Effects of Atomic Radiation.

Earlier this year a preliminary estimate of gonadal doses were made. The report enclosed here represents an effort to prepare a comprehensive survey of radiation exposures of genetic consequence. This section, and the other sections of the report, which will be distributed subsequently, are presented in this preliminary manner in order to facilitate criticism before the final publication of this survey. We should therefore appreciate any criticisms and suggestions for additions or omissions with regard to this section of the report.

Table 28 contains a brief summary of the estimated average gonadal doses under both "miminum" and "probable" headings. The minimum average doses have been computed on the basis of the lowest gonadal doses reported. Even further reduction can be obtained since improved techniques are used for some procedures for which the gonad doses are not yet measured. The probable average doses are based on an average of these reported measurements of techniques generally employed.

As indicated in the text, no distinction is made between radiologists and non-radiologists with regard to the gonad dose figures employed. This is necessary at this time because no quantitative data exists for non-radiologists. Though there is much evidence (unpublished) which establishes that procedures used by non-radiologists are much less precise and result in appreciably higher gonadal doses, we are unable to assign definite factors for this, and the probable averages in Table 28 are therefore conservative.

We believe that a systematic experimental survey of generally employed procedures, particularly among non-radiologists, is required. As is indicated in the text, more comprehensive accumulation of certain statistics is also desirable. A recommendation that the public preferably seek the services of radiologists when x-rays are to be employed might also be considered.

Sincerely yours,

J.S. Laughlin
I. Pullman

Gonadal Dose Received in the Medical Use of X-Rays

Section III

of

GENETIC RADIATION DOSE RECEIVED BY
THE POPULATION OF THE UNITED STATES

A Report Prepared for the Genetics Panel of
The National Academy of Sciences'
Study of the Biological Effects of Atomic Radiation.

J. S. Laughlin
I. Pullman

Nov. 19, 1956

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III. GONADAL DOSE RECEIVED IN THE MEDICAL USE OF X-RAYS.

The public of the United States is exposed to radiation due to a variety of medical procedures. These include the diagnostic use of x-rays, the therapeutic use of x-rays (including gamma rays from isotopes) and the diagnostic use of radioisotopes. Diagnostic procedures are most important in the exposure of the age group of the population which is genetically significant. Diagnostic procedures will be considered first.

A. Diagnostic Procedures.

The most common diagnostic use of x-rays is that of roentgenography or radiography, in which the pattern of the x-rays transmitted through the patient is recorded on special x-ray sensitive film. Fluoroscopy is another common technique in which the transmitted pattern is viewed directly on a fluoroscent screen during exposure. Fluoroscopic examinations are usually accompanied by a radiographic examination, at least in hospitals, although this may not be the case in the private offices of physicians where a large number of fluoroscopic examinations are carried out. The third major technique of x-ray examination is that of photofluorography, in which visible light sensitive film is exposed to the x-ray pattern produced oh a fluorescent screen. The main advantage of this technique is its adaptability to the examination of large numbers of peoples in a routine manner. It is generally used for chest examinations and has found its greatest application in the mass tuberculosis surveys carried out over the country. Outside of these mass tuberculosis surveys, photofluorographic units are generally found only in the larger hospotals.

Other diagnostic techniques, such as motion picture x-ray photography and xerography are either in the research stage at present or are used too infrequently to warrant discussion here.

For therapeutic purposes several forms of radiation are used, the most common and oldest type also being x-rays, but generally of a higher energy than the x-rays used in diagnostic examinations. The use of the gamma rays from radium and its daughter products such as radon for cancer therapy is also historic. With the recent introduction of artificially radioactive isotopes produced in particle accelerators and in nuclear reactors, the importance of radium has diminished.

The use of radioactive isotopes is growing at a rapid rate primarily for diagnostic purposes because of the diversity of half-life of particles and of type and energy of radiation which they provide.

In the evaluation of the average gonad dose received by the population of child-bearing age from medical x-rays the statistical distribution of x-ray examinations will be considered first, and then combined with the dose received per examination to obtain an estimate of the average dose.

1. Statistical Considerations.

The number of all x-ray examinations, their distribution by age and sex, the frequency of occurrence of examinations by anatomical location and the doses received for each of these examinations will be taken up in sequence in order to arrive at an average dose for the gonads per person under thirty. The examinations to be considered first will be those by radiologists (it is assumed that examinations in hospitals are given by radiologists), general practitioners, physician specialists (pediatricians, surgeons, etc.), osteopaths, chiropodists and chiropractors. Dental x-rays and the mass chest x-ray examinations for tuberculosis will be treated separately (see Sections 2.c and 2.d, below). Separate data are available for obstetrical x-ray examinations and these are also considered in a separate section (Section 2.b, below).

a. The Number of Diagnostic X-Ray Examinations.

(1) Radiologists - Hospitals, Clinics, and Private Offices.

The number of radiographic examinations given by radiologists in hospitals, clinics, and private offices in the United States was estimated to be 25 million in 1949 (Modern Medicine, 1; Donaldson, 2). Figures on the daily volume of practice are given in Table 1. In order to get an estimate of the number of examinations in 1955 it is assumed that the same annual load is being carried by each radiologist. The ratio of the number of radiologists in 1955 to the number in 1949 is 1.275 (from line D, Table 6), which results in an estimate of 32 million radiographic examinations by radiologists in 1955.

Table 2 gives the comparative number of radiographic, fluoroscopic, and photofluorographic examinations in certain hospitals. The percentage of photofluorograms is believed to be somewhat less on the average than the 8.7% at the New York Hospital. Many hospitals do not have photofluorographic equipment but on the other hand some hospitals such as the University of Minnesota Hospital use this type of equipment much more frequently than 8.7%. Average values which will be used in this report for the frequency of use of the three main diagnostic X-ray methods in hospitals are: Radiographic-78%; Fluoroscopic-15%; Photofluorographic-7%. On this basis the numbers of examinations given by radiologists in 1955 are estimated to be 32 million radiographic examinations, 6 million fluoroscopies, and 3 million photofluorographies.

(2) General Practitioners.

A survey of the use of x-ray equipment by general practitioners has recently been made by the National Electric Manufacturers Association (NEMA) (5) and some of the pertinent findings are presented in Tables 3 and 4. 50% of the X-ray machines are fluoroscopes and 78% are radiographic machines. The annual number of radiographs taken in 1955 is calculated to be 10.5 million and the number of patients fluoroscoped is calculated at 3.7 million. The number of physicians who own x-ray equipment has increased by almost 50% between 1949 and 1955, and almost 50% of the general practitioners at present who are active and less than 65 years old own x-ray equipment.

(3) Physician Specialists.

Data on the number of physician specialists owning x-ray equipment in 1949 are presented by Modern Medicine (1) and Donaldson (2) and are shown in Tables 3 and 5. The number of specialists owning equipment in 1955 was calculated from the 1949 data by multiplying by the ratio of total specialists in each branch in 1955 to the number in 1949. This is probably a conservative estimate when compared with the rate of increase in the number of general practitioners owning x-ray equipment over the same period. The percentage increase in ownership amounted to almost 50% while the total number of general practitioners decreased slightly. The specialists are divided into the groups shown in Table 6 (see notes at bottom of table) in order to describe better the age and anatomical regions of the patients examined. Except for dermatologists and allergy specialists who are assumed to do therapeutic work only, the machines owned by the specialists are considered to be all for diagnostic use. It is assumed that the distribution and frequency of use of fluoroscopes and radiographic equipment is the same as for general practitioners (see Section (2), above), except for radiologists, who are included with the hospital examinations (see Section (1) above). The total number of radiographs taken by physician specialists (omitting radiologists) is estimated at 4.2 million per year and the number of patients fluoroscoped by them at 1.5 million per year.

(4) Osteopaths, Chiropractors and Chiropodists.

Some published data on x-ray use by this group were assembled by the Public Health Service (6) for about 1952 and are shown in Table 5. These values will be used in our calculations. It is assumed that all units are used for diagnostic purposes and that there is the same distribution and frequency of use of fluoroscopes and radiographic equipment as for general practitioners. The total number of radiographs taken per year is estimated at 5.1 million, and 1.9 million patients are fluoroscoped.

(5) Summary.

The total numbers of examinations by type of physician and by type of equipment are summarized in Table 7.

(6) Check on the Number of Radiographic Examinations.

The total number of radiographic examinations performed in the country as calculated above can be checked in an approximate manner on the basis of film consumption. The number of radiographs taken by non-radiologists was found to be about 20 million per year, while radiologists make 32 million radiographic examinations annually. The average number of films taken per examination in hospitals at present is probably between 2.7 and 3.0. Table 8 gives some published values. The total number of films taken by radiologists then ranges from 86 to 96 million per year. The total consumption of all medical x-ray film should be about 106 to 116 million sheets per year. These results will be compared with the following independent estimates and calculations (see Table 9).

(a) According to one of the large manufacturers of x-ray film

(Barron, 8), the present annual consumption of medical x-ray film is about 118 million sheets.

(b) Statistics from the Department of Commerce (9) show that in 1954 the total shipments of all x-ray film including interplant transfers (shipments from one plant to another within a company) amounted to 185.6 million square feet. Exports were estimated at 24 million square feet (based on a Department of Commerce Memo, 10). Barron (8) estimated the use of industrial x-ray film at 15 to 18 million square feet. This leaves 145 million square feet for medical x-ray film and interplant transfers. The latter is probably very small and at least one large company has none (Struck, 11).

(c) A survey made by the U.S. Public Health Service in 1951 (12) indicated that the consumption of medical x-ray film in non-federal hospitals was about 52 million sheets. This number should be increased by at least 35% to take into account film exposed in federal hospitals, by radiologists in private practice, and the difference between 1951 and 1955. The result is an estimated 70 million sheets per year by radiologists which is 25% lower than the 86-96 million sheets calculated from the number of examinations.

(d) The United Hospital Fund (13) has furnished data on the number of x-ray film taken in some fifty voluntary general hospitals in New York City which handled about 2.5% of the nation's general hospital patients. Extrapolation to the total number of admitted patients to general hospitals in the country and allowing for the number of outpatients, the total number of films taken per year in general hospitals is found to be 79 million. Details of the calculations are given in Appendix A. Allowance for non-general hospitals on the basis of admissions (American Medical Association,14) increases this number by 7% and allowance for the private practice of radiologists further increases the number by 20%. This brings the total number of films taken by radiologists to about 100 million, which is a little higher than the 86 to 96 million estimated from the number of examinations. Except for the data in part (c) the number of radiographs calculated from the examinations is in good agreement or somewhat lower than the number estimated independently and thus the contribution to the gonad dose from this part of the calculations is conservative.

b. Distribution of Examinations by Age and Sex.

The age of thirty has been found to be at present the approximate age of one generation (National Academy Report, 15), and the genetically significant dose will be that which is delivered to the gonads of the patients under thirty years of age. The number of such patients must be determined. A more accurate method for taking into account the genetic effects is to weight the gonad dose each person receives up to a given age by the probable number of children to be born subsequently to the person. This procedure has been used by the British (Osborn and Smith, 22). It is a more involved calculation and requires more detailed assumptions about the age distribution of examinations. The two methods have been compared for two particular types of examinations, radiographic examinations of the pelvic region by radiologists and fluoroscopic examinations of the genito-urinary region by radiologists. Both examinations are among the largest contributors to the probable gonad dose, each contributing about 15% of the total dose. The two methods agree to 7% on the average annual gonad dose per person. The difference is within the estimated errors contributed by other parts of the calculation such as the average gonad dose per examination and thus the more convenient approach used in this report is satisfactory. When more complete data on age distirbutions of examinations become available, the more accurate method will be employed.

The male gonads receive a higher fraction of the skin dose than the female gonads because of their greater proximity to the skin, except possibly in certain lateral views, where the thighs may offer protection. Similarly, children receive a higher dose to their gonads relative to the skin dose than do adults, although under careful conditions the absolute dose may be less because lower voltages, currents, and exposure times can be used. The number of examinations of patients under thirty years of age will be analysed by sex and in the following age groups: infants, 0-2 years old; children 2-12 years old; and adults 12-30 years old. Ordinarily, when an infant is examined the entire body is irradiated, although, when carefully carried out, a head or chest x-ray should not irradiate the gonads appreciably (Billings, 16).

The age and sex distributions of roentgenographic examinations intwo hospitals and in a children's clinic in Los Angeles have been reported by Billings (16) and the data are reporduced in Tables 10A and 10B.

Stanford and Vance (17) published some curves of the age distributions for two English hospitabs. The age distributions in five year steps were obtained for both sexes and are shown in Table 11. The percentage of examinations of each part of the body given to patients under thirty is also presented by these authors (Table 12).

Data on both radiographic and fluoroscopic examinations given in 1942 at the Trinity Hospital (18), Little Rock, Arkansas, under their Prepaid Medical Care Plan are shown in Table 13. The report claimed that the list of subscribers represented a true cross section of Little Rock. However, the number of examinations shown was stated to be less than the actual number given because a very complete examination was made of each case before hospitalization (except in case of emergency) and these were not included in the table.

The three sets of statistics in Tables 10, 11, and 13 are compared in Table 14. The average age distribution for examinations in hospitals and by radiologists to be used in this report are: Age 0-2, 3%; Age 2-12, 9%; Age 12-30, 25%, total under 30 years, 37%. When the data of Billings et al (16) are used alone in the calculation of minimum doses their subdivision of the children's age group of 2-12 years will be applied (60%, 2-7; 40%, 7-12). The sex distributions used are 54% male, 46% female for children 0-12, and 53% male, 47% female for adults between 12 and 30. It will be assumed that the same distributions hold for patients examined by general practitioners and osteopaths in the absence of spefific information for the practice of these classes of doctors. It will be assumed that pediatricians and orthopedic surgeons use their x-ray machines on children under 12, while other physician specialists, such as surgeons, except orthopedic, internists, etc., and chiropractors and chiropodists examine adults age 12 to 30.

Table 15 presents the final results of this section, listing the estimated number of examinations given annually in the United States, according to type of equipment, age and sex of patient under 30, and type of physician. Dental examinations and the mass chest x-ray examinations are not included and will be described later (see Sections 2c and 2d). Obstetrical examinations willbe treated in more detail in Section 2b.

c. Anatomical Distribution of Examinations.

Modern Medicine (1) and Donaldson (2) present a list of the distribution of all radiographic examinations by anatomical locations at the University of Minnesota Hospitals in 1947-48, which is reproduced here as Table 16. It is the most detailed study published for an American hospital. According to Donaldson (2) the distribution can be considered typical of the country as a whole. That this is so at least for broader anatomical regions can be seen from Table 17, which gives statistics taken from Donaldson (2) and from Hodges (19), for five hospitals, including the data from Table 16, arranged under the categories of gastro-intestinal, genito-urinary, chest, skull, and skeleton (bones and joints) examinations. The University of Michigan Hospital data in Table 17 are based on patient visits and a somewhat more detailed analysis taken from Hodges (19) is given in Table 18 for diagnostic statements, which averaged 1.97 per patient visit to the hospital over the ten year period 1935-1944. A diagnostic statement presumably may involve more than one film. A still more detailed breakdown given by Hodges (19) of one category, the gastro-intestinal examinations for the year 1941-42 at the University of Michigan Hospital, is shown in Table 19.

The statistics in Tables 16 through 19 are for periods before 1950. Some more recent data indicate agreement with the older distribution. The percentages of urological and obstetrical gynecological examinations performed during 1955 at the New York Hospital were 6.8% and 2.8% respectively, of the total number of radiographic examinations (Evans 20). The examinations were made in the Department of Urology and in the Lying-In Division of the New York Hospital and represent the lower limit as an index of genito-urinary examinations because some examinations performed in the Department of Radiology itself may also be of this type.

Table 20 gives the anatomical distribution of examinations in a children's clinic in Los Angeles as reported by Billings et al (16).

Several English and Australian authors have published statistics on anatomical distributions of examinations at hospotals in their countries. The data of Martin (21) for a large general hospital in Melbourne, Australia are shown in Table 21 and the data of Osborn and Smith (22) for 5 hospitals in England are given in Table 22. There appears to be a higher percentage of gastro-intestinaleexaminations at American hospitals (see Table 17) and fewer examinations of the skeleton extremities than in the English and Australian hospitals. This would tend to produce a lower gonad dose in England and Australia, compared to the United States.

Osborn and Smith list the anatomical distribution of the important abdominal and pelvic region examinations given in a children's hospital in

England. The data are shown in Table 23. The percentage of all examinations in the abdominal and pelvic regions is 8.3%, which is considerably lower than the 37% reported by Billings (16) in Table 20.

For the purposes of this report the detailed anatomical distribution of roentgenographic examinations at the University of Minnesota Hospitals (Table 16) is used for adults, and the statistics given by Billings (see Table 20) (16) are used for children as representative of conditions in this country. The frequency of salpingography, not reported for American examinations, is taken as 0.3% of female examinations, which is the average of Martin (21) and Osborn and Smith (22) (see Tables 21 and 22). This examination is low in frequency but gives the highest dose to the ovaries, except possibly for pelvimetry, which is treated separately.

Owing to lack of information on the anatomical distribution of roentgenographic examinations among physicians other than radiologists, the hospital distributions are also used for them, with the exception of chiropodists and chiropractors. It is assumed that this group examines the skeleton only and that about 10% of such examinations are in the pelvic region.

There is very little information published on the anatomical distribution of fluoroscopic examinations and this only for foreign hospitals. From Osborn and Smith's (22) data of English Hospitals (Table 22) it is calculated that 5.9% of all hospital examinations (averaged over both sexes) were barium meal and 1.7% were barium enema. Martin (21) reports 2.5% for barium enema examinations in Australia.

On the basis of private conversations with radiologists in this country it appears that fluoroscopy in hospitals is used mostly for gastro-intestinal and chest (heart) examinations and to a much lesser extent for genito-urinary examinations. We assume that 50 per cent of the gastro-intestinal and all of the heart examinations utilize fluoroscopy. About 2 per cent of the fluoroscopies involve the genito-urinary region, and we estimate that examinations of the chest region accounts for 10 per cent. The remaining 88% of the fluoroscopies are of the upper and lower gastro-intestinal system with the frequency of the former slightly predominant over the frequency of the latter. The anatomical distribution of fluoroscopic examinations which results from the above considerations is shown in Table 24. It is applied to both adults and children examined by radiologists.

Owing to the complete lack of information on the way non-radiologists use their fluoroscopy machines, it is assumed that the anatomical distribution follows that of the broad distributions for radiography given in Table 16. As in the case of radiography, 10% of the examinations by chiropodists and chiropractors are assumed to involve the pelvic region.

All photofluorograms are assigned to the chest area.

2. Dose Measurements and Calculations.

a. Doses Received During X-Ray Examinations.

Table 25 lists measured skin doses or output doses, gonad doses, and operating factors for examinations of the various parts of the body as reported in the literature. Relatively few of the references report on gonad doses and these have been for techniques used in hospitals, generally under carefully controlled conditions. The little information that has been published on techniques used in private offices by non-radiologists, especially in the handling of fluoroscopes, indicates that their patients may receive higher than normal doses (23, 24). Since it is estimated that over 50% of the fluoroscopic and about 20% of the radiographic exposures in this country are given by non-radiologists, this contribution to the dose may be quite large. Furthermore, even in hospitals the best techniques are not universally applied and examinations, especially fluoroscopy, are frequently given by internes and other physicians less skilled than radiologists in the use of x-ray machines.

The calculation of the dose to the gonads was done twice, first using the minimum measured doses published for American conditions where possible, and secondly, using estimates for the most probable dose being given to patients.

In either procedure, the gonad dose received in each examination was multiplied by the number of examinations of that type given in thirty years and the total number of roentgens was divided by the number of people in the United States who are less than thirty years old, to get the average gonad dose per person. This procedure was repeated for each examination for which information about dose and numbers of examinations was available. Table 15, already described, gives the numbers of examinations, except mass chest x-rays, dental x-rays, and obstetrical examinations which are described separately, (see sections 2b, 2c and 2d). Table 26 gives some statistics on the age and sex distribution of the United States population. For this report the population under thirty years of age was taken as 80 million.

The basic information on doses and statistics used for the minimum dose calculation is assembled in Table 27. The average gonad doses per person per generation (thirty years) are summarized in Table 28 for the various types of examinations. The total minimum dose is found to be 1.~~6~~5 roentgens, which is about 40% of the natural background dose received over the same period. That the dose may be considered a minimum value is probably best seen by examining the most abundant data, that for skin doses. Average values of skin doses for some representative examinations are shown in Table 29. The skin doses reported by Billings et al (16) are a factor of 5 to 10 times less than the overall average of the doses reported by other investigators, except for Ardran (25, 26), who has taken great pains to reduce to a minimum the output of his radiographic apparatus at the AERE, Harwell, England, and whose values for skin doses are about the same as Billings et al (16).

A summary of what are believed to be the more probable gonad doses received in thirty years is also given in Table 28 with details for each examination listed in Table 30. The total dose is calculated to be

4.7 roentgens, which is a little greater than the **average** gonad dose received from natural background radiation. The average dose for each examination was based on the measured gonad doses listed in Table 25 with measurements in the United States given the greatest weight whenever possible. For the radiographic examinations of children, the data of Billings were used because they are the only specific measurements of this type reported for children. They should be quite conservative. The abdominal dose received by female infants of age 0 to 2 years was not given by Billings and an estimate of about one-half the male dose was used. For chest and extremity examinations it was assumed, on the basis of conversations with radiologists, that infants have their entire body sprayed with radiation. To be conservative, the smallest infant dose, that given in abdominal examinations, was used. In the age group 2 to 12 years, gonad doses of 5 mr to both female and male gonads were assumed for chest and extremity examinations.

In fluoroscopy examinations it can be seen from Table 25 that the average operating time is about 3 minutes with an average output of 20 r per minute, or a total skin dose of 60 r per examination. Direct viewing of the gonads would give 6 r to the ovaries and 30 r to the testes. This is based on an average ovary depth of 10 cm and an average testes depth of 3 cm and use of the depth dose curves given by Ritter et al (27) which are reproduced in Figures 1 and 2. We assume in genito-urinary examinations that the ovaries are in view half the time so they receive a dose of 3 r per examination; the testes are in view 20% of the time and receive a dose of 6 r. For the lower GI examinations we assume a dose of one-half the above to the female gonads, or a dose of 1.5 r while the male gonads are estimated to receive 0.75 r per examination. In this connection, Martin (2) gives 4 to 1 for the female to male gonad dose ratio for the films used in a barium enema examination while Stanford and Vance (17) give 1 to 2 for the same ratio for the fluoroscopy part of the examination. We have used as an average 2 to 1 for this ratio. The average doses received from upper GI examinations were chosen by keeping the same ratio of upper GI (stomach) to lower GI (abdomen) gonad doses as received in radiography. The doses from heart fluoroscopies were calculated from the data on scattering of Hills and Stanford (28). Doses for examinations by non-radiologists were taken to be the same for examinations of similar regions by radiologists.

Fluoroscopic examinations of children are discussed by Buschke and Parker (24), Clein (29), Martin (21), and Sonnenblick (23). Doses in the female gonads range from 1 to 17 roentgens per minute with skin doses averaging about 20 r per minute. Clein claims the gonad dose per examination is closer to 0.3 r rather than 3 r as stated by Buschke and Parker. As average values, 1 r to the female gonads and 2 r to the male gonads were used for all fluoroscopic examinations of infants (0-2 years) and for genito-urinary, lower GI and pelvic region examinations in the 2 to 12 year old group. Upper GI and extremity examination doses were reduced in a manner similar to adult examination doses.

Chiropodists and chiropractors were assumed to examine the pelvic region 10% of the time and their doses were taken the same as for examinations by radiologists.

Billings et al (16) report an estimated dose of 3 mr per film to the female gonads and 1 mr per film to the male gonads for photofluorograms taken of college students in a hospital. These values were used for examinations at all ages.

b. Doses Received From Obstetric Radiography.

X-Ray examinations of women in pregnancy produce a double effect by irradiating both mother and child. The genetic effect on the mother will be on her succeeding children and this factor must be taken into account in the statistics. The genetic effect on the child is a one-shot affair and the population to be considered is the birth rate per year rather than the total population under thirty which is the sink into which fall the genetic effects of irradiation by the other types of medical examinations given. To convert the genetic effects on the fetus to the same basis as the other examinations, the annual fetal dose in roentgens is multiplied by a factor made up of the total population under thirty years divided by the product of the years in one generation times the annual birth rate. The numerical value of the factor used in Tables 27 and 30 is 0.67 (80 million divided by 30 years times 4 million).

Table 31 gives birth statistics for the United States, and is taken from the United States Department of Health, Education and Welfare (30). Listed are: 1. the total live births per year, which is now averaging 4 million per year; 2. live births by order of birth for 1954, which will be used for estimating the number of future births to each pregnant woman examined; and 3. live births attended by physicians in hospitals and births not in hospitals. 90 per cent of the live births took place in hospitals and it is assumed that this fraction alone could receive x-ray examinations.

The basic data for estimating the frequency of obstetrical x-ray examinations were kindly supplied by Professor S. Kohl (31) who has been collecting obstetrical data on IBM punched cards for several years from about ten hospitals, mostly in the New York City area but some from other parts of the country, such as Denver, Baltimore, and New Haven. Average values over the last three or four years for the frequency of various types of obstetrical examinations, of which the most important is pelvimetry, are listed in Table 32.

Although it is true that the hospitals in this survey are particularly interested in pelvimetry, the frequencies of pelvimetries averaged over primipara and multipara births range from 3 percent to 25 percent among the various hospitals in the survey and the overall average of 11 percent will be used for the national average, as well as the average frequencies of 23 percent examined in primipara births and 5 percent in multipara births. There are many articles in the literature by obstetricians in various parts of the country advocating the use of pelvimetry, especially as a routine examination, or which indicate its widespread use in primipara patients (Barter and Parks 32, Coe 33), Dell 34, Jacobs 35, Marck and Melamed 36, Schneider 37, Swenson 38, Thoms and Wyatt 39, Walsh 40).

The number of pelvimetries which will affect future births is obtained from the data on the number of births by order of births shown in Table 31. It is assumed that this represents an equilibrium condition. The probability for a woman who has one child to have a second child is given by the ratio of the number of second births to the number of first births. This procedure is repeated for the succeeding births. The data and results of the calculations are given in Table 35. The annual number of all pelvimetries is estimated to be 410,000 and the number having a genetic effect is found to be 300,000.

From Table 25, part J, the minimum dose given to the female gonads in a pelvimetry examination is reported as 0.8 roentgens for four films. This is an English measurement (Item No. 12 in Table 25-J, Martin and Williams, 41). Haas, et al, at the University of Michigan (42) measured 0.5 to 0.7 roentgen received by the fetal gonads in a three film examination (Item No. 19 in Table 25-J) which is the customary number of exposures taken. These appear to be the minimum doses one can expect in a pelvimetry examination. The maximum dose reported is about 7 roentgens (Item No. 23 in Table 25-J, Moloy and Swenson, 43).

The minimum dose will be taken as 0.7 roentgen per three film examination. An average value of all the measurements reported is about 2.5 roentgens per examination and this will be used for the probable dose.

The minimum maternal gonad doses from placentography and abdominal examinations which ordinarily require one exposure each are assumed the same as the minimum dose from an abdomen radiographic exposure. A similar assumption is made for the minimum maternal gonad dose from a chest examination. The probable gonad doses from placentography and abdominal examinations have been taken from Stanford and Vance's (17) measurement of the maternal gonad dose during an obstetric abdomen exposure (see Item No.3 in Table 25-J). The probable gonad dose from a chest examination was taken to be the same as from a radiographic chest exposure.

The number of effective annual births for these examinations is the sum of the annual number of first births, second births, etc., in hospitals each multiplied by the corresponding percent expected to have another child. (The product of columns 2, 3 and 5 in Table 33). The result is 2.5 million effective annual births which is then multiplied by the overall average percent of patients given these examinations (last column of Table 32). The difference between the frequencies of examinations given to primipara patients and multipara patients is negligible here. These examinations contribute a very small amount (about 5 percent or less) to the dose compared with pelvimetries.

It should be noted that the 410,000 estimated annual number of pelvimetries (see Table 34) is larger than the 185,000 pelvic and hip examinations estimated to be given to women by radiologists (see Table 27, item I-A-3a). It is assumed here that the pelvimetries are not included in the number of pelvic and hip radiographs and the two doses are additive. To be consistent, the examinations of the abdomen, placenta, and chest in obstetrics are also counted separately, although here the effect on the overall dose is negligible.

The results for the maternal gonad contribution to the thirty year average gonad dose per person under thirty years of age in the United States as a result of obstetrical radiography are:

Minimum dose: 0.085 roentgen
Probable dose: 0.29 roentgen

The number of x-ray examinations which irradiate the fetus is taken as the total number of hospital born children (90 percent of 4 million) times the overall average percentages of the patients given the various examinations, as listed in the last column of Table 32.

The fetal gonads usually lie closer to the skin and under this condition receive a higher dose than the maternal ovaries.

The range of fetal gonad doses reported in the literature is quite high, extending from 0.1 r to 30 r per film as is shown in Table 25, Part J. The highest doses occur in the male fetal gonads when in the vertex presentation (fetus head down with gonads high up and pressed toward the outside). This is the most common position in the later stages of pregnancy when the x-ray examination is usually performed. However, the fetal gonads lie high up in the mother and it is possible that the pelvimetry exposures will not include them. On the other hand, the gonads may come into the field of view of the chest x-ray examination, which, although it would give a smaller dose (in the neighborhood of 10 to 50 milliroentgens), is performed four times as frequently as pelvimetry. These considerations are not taken into account in the present calculation because of lack of specific data in the literature. The minimum dose to the fetal gonads in a pelvimetry examination is taken as 0.7 roentgen; the more probable dose as 4 roentgens. These doses and the doses for the other examinations which provide a much smaller contribution are listed in Table 34. The total average thirty year genetically effective gonad dose per person received in the fetal gonads from obstetrical radiography is found to be:

Minimum dose: 0.08 roentgen
Probable dose: 0.42 roentgen

The total genetically effective thirty year gonad dose per person received from obstetrical radiography as a result of the irradiation of mother and child is found to be

Minimum dose: 0.16 roentgen
Maximum dose: 0.7 roentgen

c. Doses Received in the Mass Chest X-Ray Survey Examinations.

Table 35 lists some of the available statistics on number, age, and sex distribution of the population receiving a photofluorogram under the mass chest tuberculosis survey program carried out either in mobile or stationary units. For this report the total number of people receiving a mass chest-x-ray examination per year will be taken as 20 million, of which 30% are under 30 years old. A negligible number are under 15 years of age. The sex distribution is 53% female, 47% male. No direct gonad dose measurements have been reported. Van Allen (44) has made radiation surveys around mobile and stationary installations. The air dose at about 3 feet from the patient is 3 mr per film and increases at a rate that indicates an air dose of 10 to 20 mr at the pelvic region of the patient. This is in rough agreement with the measurements of Billings et al (16) on hospital photofluorograms (see end of Section 2a) although the male gonad dose may be higher than the 1 mr found by Billings. Until measurements are reported, the data of Billings et al (14) will be used in this report. The average gonad dose per person per generation from this source of radiation is estimated at 0.005 r.

d. Doses Received During Dental X-Ray Examinations.

In 1950 about 1.6 million dental radiograms per week or 83 million per year were estimated to have been taken in the United States, according to a survey made by the American Dental Association (45). The age and sex distributions of patients receiving these radiograms are shown in Table 36A, also taken from the above survey. The average number of films per examination is 3.5.

At present (1955-1956) the estimated annual consumption of standard periaptical dental film packets is 189 million (Barron, 8) which indicates that the rate of use of dental radiograms has increased considerably since 1950. This higher value is in rough agreement with an extrapolation based on a survey of 20 dentists in Indianapolis in 1953 by Spear (46). Spear found an average of 2,772 films per dentist per year. There were 80,000 active dentists in the United States in 1953 with 93.7 percent owning x-ray equipment (47). A calculation yields 207 million radiograms for the country as a whole.

The number of films taken of patients by age and sex in 1955 is shown in Table 36B, based on 189 million radiograms and the distribution of Table 36A.

The skin dose per film received in dental x-ray examinations can vary greatly according to the techniques used, although there seem to be two ranges of doses in general practice, depending on whether a short cone (about 8 inches long) or a long cone (about 16 inches long) is used, and whether or not filtration is added. The short cone appears to be in more common usage (80 percent out of 23 machines investigated in Kentucky (48), 2 out of 3 machines in San Francisco (49), and about half of 20 machines in Indianapolis (46)). The great majority of x-ray machines in practice appear not to have added filtration. Without filtration the skin dose per exposure with the short cone ranges from about 5 to 15 roentgens (see Table 25-K). With filtration of 1 to 2 mm. aluminum the dose can be reduced to about 2 to 4 roentgens per film. The use of the long cone without added filtration reduces the dose to about 2 roentgens per film. With the addition of 2 mm. aluminum and with the use of higher voltages and ultra fast film, Etter (50) reports a dose of 0.07 roentgen per film. Table 25-K presents some of the measured skin doses reported by various investigators. It is apparent that a full mouth examination involving 14 to 30 exposures can give a dose to parts of the face of 100 to over 300 roentgens. According to Nolan (49), patients who received such doses showed significant hematological changes.

The dose to the adult gonads from a dental x-ray examination has been measured by Stanford and Vance (17) in England. They report 0.34 mr per film to the male gonads; 0.06 mr per film to the female gonads. Their exposure times for an individual film in a whole mouth examination are much less than the exposure times used in this country, which average 3 to 3.5 seconds. Furthermore, they report the same gonad dose for a bite wing view which requires a four second exposure with all other factors the same. One would expect a dose four times as great. The measurements of Stanford and Vance are used in this report to estimate the minimum gonad dose, as shown in Table 27. The dose has been tripled for children. The thirty year gonad dose per person averages to 0.03 roentgen.

American investigators have measured the skin dose in the vicinity of the gonads and their results are given in Table 37. A summary of abdominal skin doses, estimated when necessary from the measurements, is given in Table 38. Estimates of the probable gonad dose per film, using the average of the three abdominal skin doses reported by American investigators as shown in Table 38, combined with the depth dose curves of Ritter et al (27) and with increases allowed for children, are as follows: female adults - 2 mr; male adults - 8 mr; female children - 4 mr; and male children - 12 mr. These are shown in Table 30. The average thirty year gonad dose per person amounts to 0.15 roentgen.

B. Doses Received From Radiation Therapy.

1. X-Ray Therapy.

The estimated daily number of x-ray therapy treatments in 1949 was 13,200 (Donaldson 2, see Table 1) and the number of radiographic examinations given by radiologists was 83,000. Extrapolating this ratio to the national level, using 11.8 million examinations per year given by radiologists to persons under 30 in 1955 (see Table 15), gives 1.9 million therapy treatments to persons in this age group per year at present. To this should be added the number of treatments given by dermatologists and allergists. These specialists are estimated to have owned 1,350 units in 1955 and it is assumed that the machines are all used for therapy. If each machine is used once a day, the number of treatments per year from this source amounts to 150,000 given to persons of all ages or 60,000 per year to persons under 30. We will use in this report 2 million as the total number of x-ray therapy treatments given per year to persons under 30 in this country.

There is no published information on the anatomical distribution of x-ray therapy treatments and the gonad dose per treatment, except for the approximate estimates by Clark (73). Clark estimated that about 25% of the treatments for all ages are for non-malignant ailments such as arthritis, skin diseases, bursitis, etc. The remaining 75% of the treatments are for malignant diseases and their genetic effects will be neglected because of the severity of the affliction.

Clark has also estimated that in 80% of the treatments the gonad dose is 0.5% of the skin dose and is 10% of the skin dose in the remaining 20% of the treatments. The average gonad dose is 2.4% of the skin dose and the average skin dose is 75 roentgens per treatment. The total number of roentgens absorbed per year by the gonads is estimated at 75 x 0.024 x 0.25 x 2,000,000, or 900,000 roentgens to be distributed among 80 million people under thirty years of age. This results in an average gonad dose per person in 30 years of about 0.3 roentgens.

2. Radioisotope Therapy.

In addition to the use of external x-rays for therapeutic purposes, the application of radioactive isotopes, mainly for therapy but also in diagnosis, is increasing at a rapid rate. Two of the most important isotopes in medical work are I-131 and P-32; and Clark (73) has made approximate calculations of the gonad dose received from these radioactive materials on the basis of several assumptions about the amount of decay during shipment and the distribution and rate of excretion within the body. Although a great many assumptions have to be made the results probably give the order of magnitude of the effect. Clark finds the dose per year to the gonads averaged over the entire population of the United States to be 1 mr per person from the I-131 gamma rays, 2 mr per person from the I-131 beta rays and 5 mr per person from the P-32 beta rays. These values are based on 557 curies of I-131 and 153 curies of P-32 shipped in 1954. The total thirty year dose to the gonads of persons under thirty from these isotopes is found to be about 0.2 roentgens.

3. The Use of X-Rays In Treating Sterility.

In addition to the above mentioned therapeutic applications of x-rays, x-rays are also used in curing sterility in women by directly irradiating the ovaries. References 74 to 81 constitute a small number of the published papers on this subject. Frequently the pituitary gland is also irradiated. Treatment of male sterility by irradiating the testes does not appear to be successful (Kaplan, 74). Kaplan (74) in New York City reported on 617 women treated over a period of 25 years between 1925 and 1952. Out of 482 women followed up, 251 became pregnant, 217 failed to respond and 14 did not conceive for other reasons so the cure rate was about 54% (Note: ih 1954 Kaplan (81) stated that 270 women had become pregnant). According to Kaplan (74), Mazer and Israel in 1946 reported on 78 sterile women treated by radiation of whom 65 or 83% became pregnant, and Israel (77) reporting in 1952 on 90 cases followed out of 124 treated between 1936 and 1950 found an overall cure rate of 71% in treating amenorrhea with 27 subsequent pregnancies. Kaplan (74) also refers to Playfair and Booth in England who obtained 67% favorable responses in treating 21 cases, and Asherman in Israel who obtained a cure rate of 33% in 90 cases. Mazer (74) of Philadelphia in a discussion of Kaplan's article stated that he treated nearly 800 patients between 1928 and 1952. 494 of these patients were followed for a period of 9 years. Out of these 494, 176 women were treated specifically for sterility and 71% eventually conceived. The remaining 318 women were treated for menstrual dysfunction and pregnancy statistics were not given. Rakoff (75) in Philadelphia reported on 40 cases located over a period of about 3 or 4 years with pregnancies having resulted at the time of the article in 14 or 35% of the cases. Williams (78) in Springfield, Mass. discussed 412 cases treated over a period not stated but apparently 5 to 10 years with a 40% cure rate. Roberts (78) of New Haven, Conn., in discussing Williams' article said that he also treated sterility by this technique.

From the literature consulted it would appear that about 150 women a year are treated for sterility with x-rays in this country with a cure rate averaging about 50%. The physical factors used in the treatment are: 140 to 200 KVP, 10 to 20 ma, 50 cm. focus-skin distance, with 1 to 5 mm Al filtration plus 0.5 mm Cu as filter in some cases. (76, 77, 78, 80). Drips (76) used an exposure time of 5 minutes. Usually, three treatments are given at weekly intervals with sometimes a fourth added. The skin dose per treatment has been estimated between 50 and 100 r, averaging 75 r, with a similar dose given to the pituitary area when it is treated. The total gonad dose has been estimated at 60 to 105 r, averaging about 70 r (77, 79, 82). The total yearly gonad dose given to women who become pregnant in the country is calculated to be 5,250 r, which averages to 0.002 r per person under 30 years over a thirty year period. Although this is a small contribution to the overall medical dose rate, the gonad dose received by each woman is about equal to or perhaps larger than, the doubling dose for mutations (15).

The average thirty year genetically effective gonad doses per person from radiation therapy treatments are shown in Table 28. Owing to lack of data no distinction is made between minimum and probable doses.

C. Summary

Table 28 summarizes the thirty year genetically effective gonad doses per person estimated to be received from medical x-ray diagnostic examinations and from radiation therapy in the United States on the basis of 1955 population statistics and estimated frequencies, age, and sex distributions of examinations. An estimate of the minimum possible average dose can be obtained with the assumption that all examinations are carried out with the best techniques reported. The estimate of the probable average dose actually received by the population is based on values for the various diagnostic procedures intermediate between the lowest and highest reported. The minimum estimate for the diagnostic dose is 1.~~6~~5 roentgens, while the probable average is 4.[illegible] roentgens. A detailed listing of the various examinations, the average gonad doses they are estimated to produce, their frequency, age, and sex distribution, and the percentage contribution of each examination to the total dose is given in Table 27 for the minimum dose, and in Table 30 for the probable dose. The great variety of techniques used in diagnostic examinations and the present lack of sufficient statistical information on the numbers of examinations and the age and sex distributions of the patients make it difficult to say how accurate these figures are but we feel that the overall gonad doses per person per generation are correct to within a factor of two. The largest source of error in the total dose lies in the fluoroscopy examination contribution because of the great variability in time and positioning under which such examinations are performed.

The dose due to radiation therapy is a rough estimate because the supporting data available at present are fragmentary, particularly the statistics on the frequency of examinations. No distinction has been made between minimum and probable dose. The thirty year estimate for the genetically effective gonad dose is 0.3 roentgen per person for x-ray therapy and 0.2 roentgen per person for radioisotope therapy. These figures are probably good to a factor of two or three at best. However, relative to the diagnostic dose their contribution is small and is of the order of 10 to 30 percent of the total dose. The total thirty year therapy dose amounts to 0.5 roentgen with a possible range of 0.2 to 1 roentgen per person.

The thirty year effective gonad dose per person for both x-ray diagnostic examinations and radiation therapy treatments thus is estimated to be at least 2 ± 1 roentgens and is more probably about 5 ± 3 roentgens.

The multiplying factor for converting roentgens into rads is between 0.9 and 0.95 for the x-ray energies used in diagnostic and therapy procedures (see Table 1, Section I of this report). This correction is negligible compared to the other uncertainties in the calculations and will not change the final results within the significant figures given.

Table 1

Estimated Daily Volume of Radiological Practice

Based on Annual Average
For Year 1949

(Modern Medicine, 1; Donaldson, 2)

7200	Examinations and treatments per radiologist - 306 days
23.5	Per radiologist per day
3000	Radiologists, full specialty - certified
500	Radiologists, special interest - non certified
600	Second and third year residents
4100	Radiologists, assistants and residents - 23.5 examinations each per day
96350	Examinations and treatments per day
82000	Patients - 20 per radiologist per day
13200	Treatments - 16.2% of patients therapy
68800	Roentgenographic patients
83000	Examinations 2.5 films each - 207,500 films per day. 1.2 examinations per patient

Annual Data

21,000,000	Roentgenographic patients
25,400,000	Roentgenographic examinations
63,500,000	Films
4,040,000	Therapeutic treatments

Table 2

Comparative Distribution of X-Ray Diagnostic Examinations

A. University of Minnesota Hospitals (1, 2)

	No. of Exams, 1947-48	% of Total
Radiographic examinations	30,355	51.88%
Photofluorograms	19,677	33.64%
Fluoroscopic examinations	8,465	14.48%
Total	58,497	100.00%

B. Mt. Sinai Hospital, New York City (3)

Year -	1950	1951
Number of all examinations	43,569	40,127
Number of fluoroscopic examinations	7,836	6,170
Percentage of fluoroscopic examinations	17.9%	15.4%

C. New York Hospital (4)

	No. of Examinations in 1955*	Percentage
Radiographic	78,498	79.1%
Fluoroscopic**	12,109	12.2%
Photofluorograms	8,549	8.7
Total	99,156	

Total Radiographic Films 238,899

Average number of films per exam 3.04

* From Department of Radiology

**Does not include fluoroscopic examinations made in the Pediatrics Department (estimated at 1000 per year) and on fluoroscopes stationed on some of the hospital floors. The Department of Radiology does make the radiographic examinations on the pediatric cases and some fluoroscopic examinations, which are included in the above data.

Table 3

The Number and Type of X-Ray Equipment Owned by General Practitioners in the United States in 1949 and 1956

(Modern Medicine, 1; NEMA, 5)

	1949 (1)	1956 (5)
Number of general practitioners	73,079	65,832
Number below age 65 and active		58,126
Number owning X-Ray equipment	19,680	28,800
Number of diagnostic x-ray units		28,500

Ownership in 1956 by Type of Machine* (NEMA, 5)	Number	Percent of Total Owners of Equipment
Vertical fluoroscope	14,400	50%
Radiographic units associated with vertical fluoroscopes**	8,200	
Regular radiographic unit	11,000	38%
Portable radiographic unit	2,300	8
Mobile radiographic unit	800	3
Therapy	300	1
Total radiographic units	22,300	

* The numbers in this table were extrapolated from the NEMA survey which was sent out to 9500 physicians, of whom 2274 replied.

**57.3% of the owners of vertical fluoroscopes reported that their machines were of the x-ray table type with fluoroscope attachment.

Table 4

Frequency of the Number of Radiographs Taken and the Number of Patients Fluoroscoped per Week by General Practitioners

For the United States - 1956

(NEMA Survey, 5)

No. of Radiographs per Week	Doctors
0-5	455
5-10	298
10-20	204
Over 20	159
Not indicated	7
	1123

Average number of radiographs per week (based on midpoint of each frequency range and using 25 for the range over 20) = 9

No. of Patients Fluoroscoped per Week	Doctors
0-5	776
5-10	197
over 10	150

Average number of patients fluoroscoped per week (based on midpoint of each frequency and using 15 for the range over 10) = 5

Table 5

The Distribution of Diagnostic X-Ray Equipment Among Hospitals and Physicians in the United States in 1949.

(Modern Medicine, 1, U. S. Public Health Service, 6)

	Location	Number of X-Ray Equipment Installations	Approximate No. of Units Per Installation	No. of X-Ray Units
1.	Hospitals	5200	3	13000*
2.	Clinics and other groups	1000	2	2000
3.	Radiologists	1300	2.5	3000
4.	General practitioners	19680	1	20000
5.	Physician specialists	11360**	1	11400
6.	Osteopaths***	3800	1	3800
7.	Chiropractors***	7300	1	7300
8.	Chiropodists	3000	1	3000
	Total	52640		63500
9.	Dentists	65000	1	65000

* Does not include 1850 duplicate installations used for therapy.

** Does not include 1210 units owned by dermatologists and allergists assumed to be used only for therapy.

*** According to (5) osteopaths use X-rays for diagnosis and therapy; chiropractors use X-rays for diagnosis only. All units consumed used for diagnostic purposes.

Note: The data in lines 1-5 are based on a Modern Medicine Survey, (1). The numbers for chiropodists and dentists were calculated by the Public Health Service (6) from data furnished by the National Association of Chiropodists and by the American Dental Association. For Osteopaths it was assumed that the same proportion of these practitioners owned X-ray equipment as did Doctors of Medicine, on the basis of information supplied to the Public Health Service by the American Osteopathic Society. This assumption was also used for the chiropractors.

Table 6

Estimated Distribution of Physician Specialists in the United States Owning their Own Roentgen Ray Units by Type of Practice in 1949 and in 1955.

(Modern Medicine, 1; American Medical Directory,7)

	Type of Practice	Number of Physicians in Practice		Estimated Number Owning X-Ray Equipment	
		1949	1955	1949	1955*
A.	Pediatrics	6,321	8,096	750	960
	Orthopedic Surgery	2,532	3,398	810	1090
	Total	8,863	11,494	1,560	2,050
B.	General Surgery	19,976	20,757	3,000	3,100
	Internal Medicine	12,079	16,321	2,200	3,000
	Industrial Medicine	2,122	2,178	840	860
	Urology	2,869	3,143	700	770
	Gastroenterology and Tuberculosis	2,277	2,011	200	180
	Obstetrics and Gynecology	6,798	8,582	180	230
	Eye, Ear, Nose and Throat	10,788	10,488	1,090	1,060
	Cardiology	916	1,144	290	360
	Total	57,825	64,544	8,500	9,560
C.	Dermatology	2,110	2,344	1,050	1,170
	Allergy	703	807	160	180
	Total	2,803	3,151	1,210	1,350
D.	Radiologists	3,559	4,540	1,300	**

* Calculated from the 1949 data by multiplying by the ratio of the number of physicians in practice in 1955 to the number in 1949.

**See text, Page 2, Section 1-a-(1).

Notes: Groups A and B - units assumed used for diagnostic purposes only.
Group A - assumed to examine children below 12 years only.
Group B - assumed to examine adults between 12 and 30 years old only.
Group C - assumed used for therapy only.

Table 7

The Total Number of X-Ray Examinations Given per Year
By Type of Physician and Type of Equipment
(Dental and Mass Chest X-Rays Excluded)
Estimated for 1955

	Radiographic	Fluoroscopic	Photofluorograms	Total
		Milliohs of Examinations		
1. Radiologists including Hospitals	32	6	3	41
2. General practitioners	3.2	3.7	none	17
3. Pediatricians and Orthopedic Surgeons	0.25	0.26	none	0.5
4. Other Physician Specialists*	1.2	1.2	none	2
5. Osteopaths	0.5	0.5	none	1
6. Chiropractors and Chiropodists	1.2	1.4	none	3
Total	38	13	3	54

* Other Physician Specialists are made up of the list in Part B of Table 6.

Table 8

The Average Number of Films Per Examination in Hospitals

1.	Estimate by a large film company for general hospitals in 1956 (8)	2.7
2.	New York Hospital for 1955 (4) 78,498 exams, 238,899 films	3.04
3.	Mt. Sinai Hospital (N.Y.C.) (3) 1950, 43,569 exams, 117,827 films 1951, 40,127 exams, 124,893 films	 2.7 3.1
4.	Los Angeles hospitals in 1955 (16) Private General Hospital, 1,272 films County General Hospital, 1,701 films	 5.1 2.3
5.	Estimated by Donaldson in 1949 (2)	2.5
6.	Average reported by U.S. Public Health Service c. 1950 (6)	2.7
7.	Average used in this report	3

Table 9

X-Ray Film Consumption in the United States

A. Estimated by Mr. L. E. Barron, X-Ray Sales Supervisor of E. I. DuPont de Nemours Co. (New York City office) for the entire country in 1955 (8).

Medical X-Ray Film	118 million sheets at an average size slightly larger than 1 square foot per sheet.
Dental X-Ray film	189 million packets of standard size perioptical film. This amounts to about 2.5 million square feet.
Industrial film	15-18 million square feet.

B. From Department of Commerce (9, 10) for 1954.

Total shipments of all x-ray film - 185.6 million square ft.

Exports estimated 24 million square ft.

Industrial film (using data in A above) 15-18 million sq. ft.

Leaving for medical and dental about 145 million square ft.

C. From U. S. Public Health Service (12) for 1951.

Estimated for non-federal hospitals.

Medical x-ray film	8" x 10"	12 million	± 31%	sheets
	10" x 12"	16.9 "	± 24%	
	14" x 17"	23.5 "	± 22%	
	Total	52.4 million** with range for 90% probability of 42.4 to 65.4 million sheets		

Dental x-ray film 3.19 million ± 28% sheets

* Error shown is for 90% probability

**Average size is 1.14 square feet per sheet

Tables 10A and 10B

Age and Sex Distribution of Roentgenographic Examinations in Los Angeles - Year 1955 (Billings et al, 16)

10A

		Private General Hospital	County General Hospital
Number of Patients		251	560
Sex:	Male	51%	-
	Female	49%	-
Age (Years)	0-11	3%	15%
	12-30	9	30%
	31-40	8	14%
	41-50	15	12%
	51-plus	65	29%
	Total	100%	100%
Total number of exposures		1272	4701
Average no. per examination		5.1	2.3

Percentage under 12 weighted by exposure 12%

" " 30 " " " 38%

10B

		Children's Clinic
Number of Patients		125
Sex:	Male	54%
	Female	46%
Age (Years)	0-2	23%
	2-7	46%
	7 plus	31%
Number of exposures		377%
Average no.per exam.		3.0

England. The data are shown in Table 23. The percentage of all examinations in the abdominal and pelvic regions is 8.3%, which is considerably lower than the 37% reported by Billings (16) in Table 20.

For the purposes of this report the detailed anatomical distribution of roentgenographic examinations at the University of Minnesota Hospitals (Table 16) is used for adults, and the statistics given by Billings (see Table 20) (16) are used for children as representative of conditions in this country. The frequency of salpingography, not reported for American examinations, is taken as 0.3% of female examinations, which is the average of Martin (21) and Osborn and Smith (22) (see Tables 21 and 22). This examination is low in frequency but gives the highest dose to the ovaries, except possibly for pelvimetry, which is treated separately.

Owing to lack of information on the anatomical distribution of roentgenographic examinations among physicians other than radiologists, the hospital distributions are also used for them, with the exception of chiropodists and chiropractors. It is assumed that this group examines the skeleton only and that about 10% of such examinations are in the pelvic region.

There is very little information published on the anatomical distribution of fluoroscopic examinations and this only for foreign hospitals. From Osborn and Smith's (22) data of English Hospitals (Table 22) it is calculated that 5.9% of all hospital examinations (averaged over both sexes) were barium meal and 1.7% were barium enema. Martin (21) reports 2.5% for barium enema examinations in Australia.

On the basis of private conversations with radiologists in this country it appears that fluoroscopy in hospitals is used mostly for gastro-intestinal and chest (heart) examinations and to a much lesser extent for genito-urinary examinations. We assume that 50 per cent of the gastro-intestinal and all of the heart examinations utilize fluoroscopy. About 2 per cent of the fluoroscopies involve the genito-urinary region, and we estimate that examinations of the chest region accounts for 10 per cent. The remaining 88% of the fluoroscopies are of the upper and lower gastro-intestinal system with the frequency of the former slightly predominant over the frequency of the latter. The anatomical distribution of fluoroscopic examinations which results from the above considerations is shown in Table 24. It is applied to both adults and children examined by radiologists.

Owing to the complete lack of information on the way non-radiologists use their fluoroscopy machines, it is assumed that the anatomical distribution follows that of the broad distributions for radiography given in Table 16. As in the case of radiography, 10% of the examinations by chiropodists and chiropractors are assumed to involve the pelvic region.

All photofluorograms are assigned to the chest area.

Table 12

The Percentage of Patients Under 30 Years of Age Undergoing Various Anatomical X-Ray Examinations in English Hospitals

(Stanford and Vance, 17)

	Patients Under 30 Years, Percent			
	Male		Female	
Examination Hospital*	A	B	A	B
Skull, sinuses and mastoid	53	45	52	42
Chest	44	40	52	50
Shoulder and cervical spine	29	37	29	20
Dorsal spine	27	15	30	70
Lumbar spine and sacroiliac joint	18	29	24	16
Pelvis	34	14	22	38
Hip	22	40	30	23
I.V.P.	15	13	30	12
Gall-bladder	16	0	7	0
Abdomen	36	67	43	50
Pelvimetry	-	-	63	63
Barium meal and barium enema	17	10	17	8
Hand, arm, foot and leg	47	55	40	37

* Hospital A - Guy's Hospital, London
Hospital B - Hartford County Hospital, Hartford

Table 13

Age Distribution of Radiographic and Fluoroscopic Examinations For Year 1942

(Trinity Hospital Prepaid Medical Care Plan, Little Rock, Ark.,18)

		Number of Diagnostic X-Ray Services		Number of Fluoroscopies	
		Office	Hospital	Office	Hospital
Subscribers:	All ages	337	43	49	6
	15-19 years	2	-	1	6
	20-24	17	1	3	-
	25-29*	39	6	10	1
	30-34*	40	7	11	1
	35-44	92	11	5	2
	45-64	138	17	17	1
	65 and over	9	1	2	1
Dependents:	All ages	284	40	28	5
	Less than 1 yr.	2	3	1	1
	1-2	6	-	-	-
	2-5	27	3	2	1
	5-9	35	1	5	-
	10-14**	33	3	8	-
	15-19	36	5	2	-
	20-24	9	1	-	-
	25-29*	22	3	1	-
	30-34*	22	3	2	-
	35-44	50	11	3	-
	45-64	42	7	4	3
	65 and over	-	-	-	-

* Estimated from reported data on 25-34 year group.
**10-14 year group prorated 40% to 10-11 year olds.

	X-Ray Examination		Fluoroscopies	
	Number	Percent	Number	Percent
Total examinations, all ages	704		88	
Examinations to children to 12 -	91	13%	13	15%
" " adults 12-30	164	23	23	26
" " infants 0-2	11	1.6(12%)*	2	

*Percent of children under 12

Table 14

Age and Sex Distribution of Patients Undergoing Radiographic and Fluoroscopic Examinations

Summary and Comparison of Tables 10, 11, and 13

Age Group	Type of Exam.	Percent of Total Exams From Table 9 (Los Angeles)	From Table 10 (England)	From Table 11 (Little Rock)	Average Values Used in this Report Percent
0-2 years	Radiographic	3	-	2	3
2-12 "	"	9	-	11	9
0-12 " Total	"	12	13	13	12
12-30 "	"	26	26	23	25
0-30 " Total	"	38	39	36	37
0-2 years	Fluoroscopic	-	-	2	3
2-12 "	"	-	-	13	9
0-12 " Total	"	•	*	15	12
12-30 "	"	-	-	26	25
0-30 " Total	"	-	-	41	37
	Sex				
0-12 years	Male Rad.	54	55		54
0-12 "	Female "	46	45		46
12-30 "	Male "	51	55		53
12-30 "	Female "	49	45		47

Table 15

The Number of X-Ray Examinations Given Per Year to Patients Under 30 Years of Age According to Type of Physician, Type of Equipment and Age and Sex of Patient for 1955

(Dental and Mass Chest X-Rays Excluded)

	Number of Examinations, Millions per Year						
	Age - -0-2		2-12		12-30		
Type of Physician	Sex - Male	Female	Male	Female	Male	Female	Total
	Radiographs (Films) (Average 3 Films per Examination)						
1. Radiologists, including hospitals	1.56	1.32	4.65	3.99	12.75	11.25	35.4
2. General Practitioners	0.17	0.14	0.51	0.43	1.38	1.23	3.9
3. Pediatricians and Orthopedic Surgeons	.09	0.08	0.31	0.27	-	-	0.8
4. Other Physician Specialists*	-	-	-	-	0.46	0.41	0.9
5. Osteopaths	0.02	0.02	0.07	0.06	0.19	0.17	0.5
6. Chiropractors and Chiropodists	-	-	-	-	0.49	0.44	0.9
Total	1.8	1.6	5.5	4.8	15.3	13.5	42.5
	Fluoroscopic Examinations						
1. Radiologists, including hospitals	0.10	0.09	0.30	0.26	0.82	0.73	2.3
2. General Practitioners	.06	0.05	0.18	0.16	0.49	0.44	1.4
3. Pediatricians and Orthopedic Surgeons	.03	0.03	0.11	0.09	-	-	0.3
4. Other Physician Specialists**	-	-	-	-	0.16	0.15	0.3
5. Osteopaths	0.008	0.007	0.02	0.02	0.07	0.06	0.2
6. Chiropractors and Chiropodists	-	-	-	-	0.18	0.16	0.3
Total	0.2	0.2	0.6	0.5	1.7	1.5	4.8
	Photofluorograms						
1. Radiologists, including hospitals	0.05	0.04	0.15	0.12	0.40	0.36	1.1

*Other Physician Specialists are made up of the list in Part B of Table 6

Table 16

Anatomical Distribution of X-Ray Examinations for All Ages At the University of Minnesota Hospitals in 1947-1948

(Modern Medicine, (1); Donaldson, (2))

		Percent of All Hospital Examinations
Genito-Urinary System		
Pyelography, excretion		2.82
Pyelography, retrograde		1.32
Urinary tract		2.60
	Total	6.74
Gastro-Intestinal System		
Abdomen		6.34
Colon		5.66
Stomach, duodenum, esophagus		12.22
Small bowel		0.44
Cholangiogram		0.59
Gall bladder area		1.98
	Total	27.23
Skeleton-Pelvic Region		
Pelvis and hips		4.16
Thigh, leg and knees		3.27
Spine		6.47
Sacroiliac		1.27
	Total	15.07
Skeleton-Extremities and Chest Region		
Arm, forearm, elbows		1.38
Shoulder girdle		1.15
Ribs and sternum		0.58
Wrist and hand		1.58
Ankle and foot		1.85
	Total	6.54
Chest Region		
Chest		33.01
Heart		2.08
Bronchogram		0.48
	Total	35.57
Head Region		
Skull orbits, sella turcica		4.42
Sinuses, paranasal and mastoids		1.80
Facial bones		0.77
Ventriculogram		0.47
Encephalogram		0.38
	Total	7.84
Miscellaneous		1.01
	Total	100%

Total number of roentgenographic examinations: 30,355

Table 17

Anatomical Distribution of Examinations In Some Teaching and Non-Teaching Hospitals

Hospital Symbol*, Year		Genito-Urinary	Gastro-Intestinal	Bones, Joints	Chest	Skull	Bedside	Total
A (1945)	No.	1,455	4,234	4,406	5,604	1,431		17,130
"	%	8.5%	24.7	25.7	32.7	8.4		100%
B((1948)	No.	735	3,428	6,843	5,239	1,108		17,353
"	%	4.2	19.7	39.4	30.2	6.4		100%
C (1949)	No.	1,730	2,180	8,731	9,437	2,106		24,184
"	%	7.2	9.0	36.1	39.0	8.7		100%
D (1947)	No.	2,132	8,192	6,385	10,908	2,435		30,052
"	%	7.1%	27.2	21.2	36.3	8.1		100%
E (1942)	No.	1,956	5,591	11,010	8,995	3,136	1,266	31,954
"	%	6.1	17.5	34.4	38.1	9.8	4.0	100%
E (1943)	No.	1,992	5,974	11,787	9,888	3,561	1,248	34,450
"	%	5.8	17.3	34.2	28.7	10.3	3.6	100%
E (1944)	No.	2,001	6,128	13,037	10,121	3,446	1,354	36,087
"	%	5.6	17.0	36.2	28.1	9.5	3.7	100%
E(1935-'44)	No.	18,277	57,820	114,349	115,137	34,372	13,696	353,651
"	%	5.2	16.3	32.4	32.6	9.7	3.9	100%
A+B+C+D +E(1944)	No.	8,053	24,162	39,402	41,309	10,526	1,354	124,806
	%	6.5	19.4	31.6	33.2	8.3	1.1	100%

* A. Grace Hospital, Detroit, Michigan, From Donaldson (2)
B. St. Joseph Mercy Hospital, Ann Arbor, Mich. From Donaldson (2)
C. Kern County Hospital, Bakersfield, Calif. From Donaldson (2)
D. University of Minnesota Hospitals, Minneapolis, Minn. From Dohaldson (2)
E. University of Michigan Hospital, Ann Arbor, Michigan. From Hodges (19). The numbers for the University of Michigan Hospital are patient visits. The number of diagnostic statements over the ten year period 1935-1944 was 692,450 or 1.97 per patient visit. Each statement may involve more than one film. See Tables 16 and 17.

Table 18

Distribution of Diagnostic Statements*
University of Michigan Hospital 1935-1944 (Hodges, 19)

Region	Number		Percent of Total	
Skull				
a) Facial bones		19,577		2.8%
b) Cranium		22,813	-	3.3%
Total	42,390		6.1%	
Skeleton				
a) Spine		91,714		13.2%
b) Upper extremities		39,942		5.8%
c) Lower extremities		115,358	-	16.6%
Total	247,014		35.6%	
Chest				
a) Mediastinum (Neck, thoracic cage, cardio-vascular system)		52,644		7.6%
b) Lungs and pleura (non-tuberculosis)		117,544		17.0%
c) Intrathoracic tuberculosis		106,110	-	15.3%
Total	276,298		39.9%	
Abdomen				
a) Gastro-intestinal		97,261		14.1%
b) Genito-urinary		29,487	-	4.3%
Total	126,748		18.4%	
Grand Total	692,450		100%	

*-Diagnostic statements presumably may include more than one exposure.

Table 19

Details on Distribution of Gastro-Intestinal Examinations University of Michigan Hospital 1941-1942 (Hodges, 19)

Region	Number	Percent
Upper G.I.	2,120	19.4
Esophagus	175	1.6
Stomach and small bowel	1,377	12.6
Biliary tract	2,958	27.1
Colon	2,602	23.8
Abdomen, generally	1,693	15.5
Total	10,925	100.0%

Total patient visits for G.I. examination - 6,528 or 18.6% of total visits.

Total patient visits for all x-ray exams - 36,099

Table 20

Distribution of Radiographic Exposures in a Children's Clinic

(Billings et al, 16)

Anatomical Region	Percent
Abdominal region	15%
Pelvis and Hips	22
Lower extremities	5.5
Upper extremities	4.5
Chest	27
Skull	26
Total	100%
Total exposures	377, 54% male, 46% female

Table 21

Anatomical Distribution of X-Ray Examinations for All Ages By Sex in an Australian Hospital

(Martin, 21)

	Percent of All Hospital Exams of Each Sex	
	Male	Female
Genito-Urinary System		
Pyelography excretion	2.3	2.3
Pyelography, retrograde	0.4	0.5
Bladder	0.6	0.3
Kidneys	0.2	0.2
Urinary tract	5.5	4.9
Salpingography	0	0.2
Total	9.0	8.4
Gastro-intestinal System		
Intestinal tract (barium enema)	2.5	2.4
Stomach	8.3	5.4
Cholecystography	1.4	4.6
Gall bladder	1.9	4.6
Liver	0.1	0.1
Total	14.2	17.1
Skeleton-Pelvic Region		
Pelvis	2.6	2.8
Hips	2.7	3.2
Lumbosacral joint	4.5	3.4
Dorsal vertebrae	2.4	2.1
Total	12.2	11.5
Skeleton-extremities and Chest Region		
Extremities	26.8	17.5
Cervical vertebrae	1.5	1.7
Shoulders	2.4	1.5
Ribs	0.5	0.8
Total	31.2	21.5
Chest	20.8	29.1
Skull, etc.	12.6	12.4
Total	100%	100%

Percentage of examinations on males: 52.7%; on females: 47.3%
Total number of cases in sample: 15,880

Table 22

Anatomical Distribution of X-Ray Examinations for All Ages by Sex in English Hospitals

(Osborn and Smith, 22)

	Percent of all Hospital Exams of Each Sex	
	Male	Female
Genito-Urinary System		
Pyelography	1.9	1.7
Bladder	0.3	0.3
Salpingogram	0	0.3
Total	2.2	2.3
Gastro-Intestinal System		
Barium meal	7.2	4.5
Barium enema	1.4	2.0
Cholecystogram	0.6	1.1
Abdomen (with obstetrics)	1.6	3.1
Total	10.8	10.7
Skeleton-Pelvic Region		
Pelvis	1.9	2.0
Hip and femur	3.8	4.0
Thoracic spine	1.4	1.7
Lumbar spine	3.8	4.0
Total	10.9	11.7
Skeleton-Extremities and Chest Region		
Arm and hand	13.2	12.1
Shoulder	2.2	1.7
Cervical spine	1.1	2.0
Rib and sternum	1.1	0.3
Leg and foot	13.7	11.0
Total	31.3	27.1
Chest		
Large film	32.4	35.2
Special	1.1	2.3
Total	33.5	37.5
Head	10.7	9.6
Teeth	0.6	0.8
Pelvimetry	0	0.3
Total	100.0%	100.0%

Percentage of examinations on males: 50.6%; on females: 49.4%
Total number of patients in sample: 21,205 (5 hospitals)

Table 23

Percentage of All X-Ray Department Patients Subjected to Certain Examinations (Abdominal and Pelvic Regions) in an English Children's Hospital

(Osborn and Smith, 22)

	Percent of all Exams.
Lumbar spine	1.57%
Abdomen	2.58
Pyelography	0.94
Pelvis	0.70
Hip and femur	2.27
Barium enema	0.25
Total abdomen and pelvic region	8.31%

Table 24

Estimated Anatomical Distribution of Fluoroscopic Examinations Used in This Report

Region		Per cent
Genito-urinary system		2
Gastro-intestinal system		
Lower GI		40
Upper GI		48
Heart		10
	Total	100%

Table 25

Data Reported in the Literature on Radiation Doses Received From Medical Diagnostic X-Ray Examinations

This table lists the skin or air doses, the gonad doses, and the physical factors including the voltage, milliampere-seconds, amount of filtration and distance of the focus or target from the film, or from the skin of the patient, which have been reported for various types of examinations of different parts of the body. The examinations are divided into the following main anatomical regions of the body.

A. Genito-urinary region
B. Lower Gastro-intestinal region
C. Upper Gastro-intestinal region
D. Pelvic region (including lower spine)
E. Chest region (including upper spine)
F. Head region
G. Extremities
H. Examinations of Children
J. Obstetrical Examinations
K. Dental Examinations
L. Summary of Fluoroscopic Examinations

The doses reported are for one exposure unless the word exam. (examination) appears in the first column, in which case the doses shown are for the entire examination as described.

The following paragraphs describe the abbreviations used.

Column 1 (Type)

(R) - radiographic exposure
(F) - fluoroscopic examination
(F+R)-Examination involves both radiography and fluoroscopy.
AP - Antero-posterior view
PA - Postero-anterior view
Obl.- Oblique view
Lat.- Lateral view
KUB - Kidney-ureter-bladder
GI - Gastro-intestinal

Columns 2, 3, and 4 (Skin and Gonad Doses)

Doses are reported in milliroentgens, mr., unless the letter "r" signifying roentgens appears next to the number. In some cases, as for example, No. B-13, the gonad dose is not specifically mentioned but a depth dose is reported which may include the female gonads at 10 cm.

Column 5 (Voltage)

KVP - kilovoltage peak
(F),(R) - same as described under Column 1

Column 6(Milliampere-seconds)

The product of current and time as milliampere-seconds is given when reported with the separate factors of milliamperes x seconds shown in parentheses, when stated. In some cases only the current is given, as milliamperes, ma.
(F), (R) - same as described under column 1.

Column 7 (Filter, mmAl)

This column gives the added filtration of millimeters of aluminum. Some x-ray machines have a built in filter, usually about 0.5 mmAl, but this is generally not stated in the literature.
(F), (R) - same as described under Column 1

Column 8 (Distance)

This column gives the distance in inches or centimeters from the focus to the film, F (without parentheses) or to the skin, S. Some fluoroscopy data give the distance to the table top, TT.
(F), (R) - same as described under Column 1.

Column 9 (Comments)

In this column the number of films per examination f/ex is given. In some cases the field size is reported. Ardran and Crookes (25) state that their skin doses as well as the doses they calculated from the data of Clark (83) and Sante (84) are without backscattering, w.o.b.s., taken into account.
calcd. - calculated.

Column 10 (References)

Reference numbers refer to the articles listed at the end of the section on medical x-ray doses and are the same as the references in the text.

Notes

A-16. Barnett and Bewley (63) stated that the average time for 20 fluoroscopic examinations was 83 sec. per exam. during which time the left ovary was irradiated for 23 seconds and an equal time is estimated for the right ovary. For the gonad doses quoted the fluoroscopy time was given as 75 sec. The screen field area in fluoroscopy was 6 sq. cm. In radiography a standard film plus Potter-Bucky Diaphragm was used.

A-24. The field size at the pelvis was 15-20 cm. diameter. 14" x 17" plates were used.

B-13. The doses were calculated by Bell (56) from data of Braestuup on the variation of dose with current and voltage.

Table 25

Data Reported in the Literature on Medical Diagnostic X-Ray Examinations
Skin or Air Doses, Gonad Doses and Physical Factors
Data are for 1 Exposure Unless Exam. is Stated in First Column
For description of abbreviations and notes, see beginning of Table

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Type	Skin or Air Dose mr.	Gonad Dose,mr.		Voltage KVP	Milliamp. Seconds (maxsec.)	Filter mmAl	Distance	Comments	Ref.
		Female	Male						
A.Genito-urinary region									
1.Bladder(R)		150							21
2.Bladder Exam(R)		210	210					1.4f/ex.Fem 1.2f/ex.Male	21
3.Cystogram, AP(R)	1400	1190		67	100	1	36"F.	Calcd.to ovaries,10cm deep	27
4.Cystogram Oblique(R)	1400	1160		66	100	1	28.2 S 36" S	Calcd.to ovaries,11cm deep	27
5.Kidneys(R)		Range6-100 Av. 30	Range2-5 Av.2.5				27.2" F		21
6.Kidney(R) exam		60	3.7					2f/ex.Fem. 1.5f/ex.Male	21
7.KUB(R)	1200			62	10 (100x0.1)	0.5	36" F		53
8.Pyelography intravenous (Renal R)	2500	200	69	72	100 (200x0.5)	none	36" F	3f/ex.	17
9.Pyelography intravenous Bladder (R)	2500	230	93	72	100 (200x0.5)	none	36" F	3f/ex.	17
10.Pyelography excretion (R)		Range 32-500 Aver.250	Range100-200 Aver.140						21
11.Pyelography excretion exam(R)		1360	590					3.9f/ex.Fem. 4.2f/ex.Male	21
12.Pyelography retrograde exam (R)		800	700					3.7f/ex.Fem. 2.9f/exMale	21

Table 25 Cont'd.

A. Genito-urinary region cont'd.

(1) Type	(2) Skin or Air Dose mr.	(3) Gonad Dose, mr. Female	(4) Male	(5) Voltage KVP	(6) Milliamp. Seconds (maxsec.)	(7) Filter mmAl	(8) Distance	(9) Comments	(10) Ref.
13. Pyelogram exam(R)	a.24000 b. c.6800		a.6400 b.2800 c.1200			a.none b. 1 c. 2		a.4f/exMale b. " " c. " "	55
14. Pyelogram intravenous AP (R)	5000				400(tot)	1	36" S.	4f/ex.	71
15. Hystero-salpingo-gagraphy exam(R)		27000							62
16. Hystero-salpingo-gnaphy exam(F+R)		a.1700 b.3200 c.3600		(F)82 (R-AP)80 (R-Lat)85	(F)225 (3x75) (R-AP)ma =75 (R-Lat)ma =150	(F)none (R) "	(F)53cm. TT. (R)82cm. S.	a.(F)+2AP Films b.(F)+2AP+ 1Lat Films c.(F)+4Films see NoteA-16	63
17. Salpingogram(R)	500	200		62	100				16
18. Salpingography(R)		2500 (tot.)							21
19. Salpingography exam(R)		25000						3.3f/ex.	21
20. Urinary tract exam(R)		203	110					2.9f/exFem. 2.9f/exMale	21
21. Urogram AP(R)	1300			62	100	1	36" F. 28.2"S.		27
22. Urogram Oblique(R)	1400			62	100	1	36" F. 27.2" S.		27
23. Urogram							Calcd.1300mr to center of abdomen, 6AP+2oblique(see21+22.)		27
24. Urography intravenous (R)		50		74-88	20-40		36" F	An exam takes 4 films see NoteA-24	54

Table 25 Cont'd.

(1) Type	(2) Skin or Air Dose mr.	(3) Gonad Dose, mr Female	(4) Gonad Dose, mr male	(5) Voltage KVP	(6) Milliamp. Seconds (maxsec.)	(7) Filter mmAl	(8) Distance	(9) Comments	(10) Ref.
A..Genito-urinary region cont'd.									
25.Urography									
a.Large survey film		220	40* 300**	72	100	2.5	100cm F. 77cm S.	*precise beam **wide beam	85
		90	15* 120**	120	13	2.5	100cmF. 77cmS.		
b.Kidneys		24		72	100	2.5	100cmF.	LargeSurvey Film size 30cmx40cm	
spot film		12		120	13	2.5	77cm S.		
c.Bladder spot film 25°		280	97* 700**	72	100	2.5	58 cm S.		
		110	39* 80**	120	13	2.5	58 cm S		
d.Bladder,		690		77	500	2.5	100 cmF.		
Lateral		410		119	60	2.5	100 cmF.		
26.Urethra- cystography			550	72	100	2.5	100cmF	Film size 24cmx30cm	85
			110	120	13	2.5	100cmF		

Table 25 cont'd.

(1) Type	(2) Skin or Air Dose, mr.	(3) Gonad Dose, mr Female	(4) Male	(5) Voltage KVP	(6) Milliamp. Seconds (maxsec)	(7) Filter mmAl	(8) Distance	(9) Comments	(10) Ref.
B. Lower Gastro-intestinal region									
1. Abdomen, AP(R)	a.460 b.210	155 75	0 0	62 120	100 10			High voltage	16
2. Abdomen AP(R)	2200	200	69	72	100 (200x0.5)	none	36" F.	1f/ex.	17
3. Abdomen, AP(R)	2400			58	210	1	36" F. 28.2"S		27
4. Abdomen, AP(R)	1250				100	1	36" S	1f/ex	71
5. Abdomen Straight(R)	150			90	15 (100x0.15)	3	100cmF. 74cmS	w.o.b.s.	25
6. Abdomen straight AP (R)	2600			70	100	none	36" F. 71cmS	w.o.b.s. calcd.from Clark(83)	25
7. Abdomen, straight AP (R)	4700			75	100	none	30" F. 56cm S.	w.o.b.s. Calcd.from Sante(84)	25
8. Barium enema exam(R)		520	130				3f/ex. Female 3.1f/ex.Male		21
9. Barium enema(F)	7500	20	40	70	360 (2x180)	none	30" F.		17
10. Colon, (PA)(R)	1000			65	75	1	36" F 28.2" S		27
11. Colon, oblique(R)	1400			69	75	1	36" F 27.2" S		27
12. Small intestine and colon AP(R)	200			90	20 (100x0.2)	3	100cmF. 74cm S	w.o.b.s.	25
13. Gastro-intestinal exam.(R)	6500	(2250 at5cm) (820at10cm)		80	25 (100x.25) Per film	0.5	36"S.	6f/ex. Field-whole abdomen+ pelvis.See Note B-13	56

Table 25 Cont'd.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Type	Skin or Air Dose, mr.	Gonad Dose,mr. Female	Male	Voltage KVP	Milliamp. Seconds (maxsec.)	Filter mmAl	Distance	Comments	Ref.
B.Lower Gastro-intestinal region, cont'd.									
14.Colon, small field (F)	50-130r	(13-34r at 5cm) (4.5-12r at 10cm)			1.5-4 min.			Field size 75 cm.	56
15.Colon, large field (F)	50-130r	(16-43r at 5 cm.) (6-16 r at 10 cm.)						Field size 208 cm.	56
16.Smalland large intestine(R)	4800			80	100	none	30" F 58cmS	w.olb.s. calcd.from Sante(84)	25
17.Colon and small intestine(R)	3300			85	60	none	30"F 56cmS	w.o.b.s. calcd.from Clark(83)	25
18.Barium enema colon exam(F+R)	Range100 to 800 Aver.420 (For fluoroscopy +spot films +large ")			(F)85	530 (3.5x150)	2.5	46cmTT	output5.2 r/m(w.o.b.s.)	54
				(R)85-95	20 per Film			Spot films (8"x10") 1to6 f/ex aver.3.2/ex.	
				(R)72-98	20-60 per film		36"F	large films (14"X17") 0to4/ex. Aver. 2.3	
19.Barium enema exam(F+R)	(R)11800 (F)15000 27000				(R)600 (F)2min.	1	36" S	2AP+4 obl. per exam.	71
20.Barium enema exam(F+R)	4900					2		Fluoroscopy +2 films +2spots	55
21.Barium enema exam(F+R)		2000-calcd. to center of abdomen			(F) 5min.			Fluoroscopy +3films +3spots	27

Table 25 cont'd.

(1) Type	(2) Skin or Air Dose mr.	(3) Gonad Dose,mr. Female	(4) Male	(5) Voltage KVP	(6) Milliamp. seconds (maxsec)	(7) Filter mmAl	(8) Distance	(9) Comments	(10) Ref.
C.Upper Gastro-intestinal region									
1.Barium meal(F)	7500	9	20	70	360 (2x180)	none	24" F		17
2.Cholecystography exam(R)		378	13.5					4.2f/exFemale 4.5f/exMale	21
3.Esophogram(R) exam(R+F)(F)	7800 15000 23000				(R)400 (F)2min	1	36" S	(R)1AP+Lat. +1 obl.	71
4.Gall bladder PA(R)	1800			58	150	1	36" F 28.2" S	Examconsists of 3PA+ 1 oblique	27
5.Gall bladder obl.(R)	2000			61	150	1	36" F 27" S	calcd.dose= 1.Ortocenter of abdomen	27
6.Gallbladder exam(R)	6400					2		5f/ex	55
7.Gallbladder PA(R)	2600	5.2	0.6	70	150 (200x.75)	none	36" F	3f/ex.	17
	1250			120				Higher voltage	
8.Gallbladder (R)	600			74	50 (125x.4)	0.5	36"F		53
9.Gallbladder (R)		Range 20 to 60 Aver.50							21
10.Gallbladder cholecystography(R)		Range 50 to 160 Aver.90	3					see no. 2 above	21
11.Gallbladder area exam(R)		70	2.7					1.4f/ex.Female 1.4f/exMale	21
12.GI PA(F)	3r/min			85	4ma				72
13.GI (R)		Range 10 to 1100 Aver.150							21
14.GI(Stomach) PA(R)	650			78	50 (125x0.4)	0.5	36" F	6f/ex.	53

Table 25 Cont'd.

(1) Type	(2) Skin or Air Dose mr.	(3) Gonad Dose, mr. Female	(4) Gonad Dose, mr. Male	(5) Voltage KVP	(6) Milliamp. Seconds (maxsec)	(7) Filter mmAl	(8) Distance	(9) Comments	(10) Ref.
C. Upper Gastro-intestinal Region (cont'd.)									
15.Upper GI exam (F+R)		Range 100 to 300 Aver. 200		see No.B-18 for Physical Factors				Aver.exam.340 sec. fluoroscopy 7 spots (8x10) 4 stomach(11"x14") 1 abdomen(14"x17")	54
16.GI Exam	13,700					2		5 films+6 spots +fluoroscopy	55
17.GI Exam (F+R)	(R)20,000 (F)15,000 35,000				(R)1275 (F)2min.	1	36" S.	(R)consists of 15 films 8AP,1Lat.,6obl.	71
18.GI (F) small field	100to 260r	(26to68r 5cm deep) (9to24r 10 cm deep)			3-8min.			Field size 75 cm^2	56
19.GI (F) Large field	100 to 260r	(33to90r 5cm deep) (12to32r 10cm deep)			3-8min.			Field size 208 cm^2	56
20.Liver(R)		20	2					1 f/ex.	21
21.Stomach PA oblique (R)	360	0-left 50-right	0	120	20			High voltage	16
22.Stomach exam(R)		360	470					2.4f/ex.Fem. 2.6f/ex.Male	21
23a.Stomach and duodenum,PA (R)	1000			65	75	1	36" F. 28.2" S.	Exam.consists of 10min.fluoroscopy, 8 spots, 5 serials	27
23b.Stomach+ duodenum obl.(R)	1400			69	75	1	36" F. 27.2S.	calcd.dose to center of abdomen=3r.	27
24.Stomach, duodenum PA (R)	270			90	20 (100x.2)	4	68 cm F. 46 cmS.	w.o.b.s.	25
25.same as(24)	2200			85	40	none	30" F 56cm S	w.o.b.s. (calcd.from Clark(83)	25

Table 25 Cont'd,

(1) Type	(2) Skin or Air dose mr.	(3) Gonad Dose, mr Female	(4) Male	(5) Voltage KVP	(6) Milliamp. seconds (maxsec.)	(7) Filter mmal	(8) Distance	(9) Comments	(10) Ref.
C. Upper Gastro-intestinal Region (cont'd.)									
26. Same as(24)	5600			89	100		30" F. 58cm S.	w.o.b.s. calcd.from Sante(84)	25
27. Stomach+ duodenum(F)	17.7r/min			80	300	1.5	15" F.		27

Table 25 Cont'd.

(1) Type	(2) Skin or Air Dose mr.	(3) Gonad Dose, mr. Female	(4) Male	(5) Voltage KVP	(6) Milliamp. seconds (maxsec)	(7) Filter mmAl	(8) Distance	(9) Comments	(10) Ref.
D. Pelvic region									
1. Hips, AP (R)	4700	210	710	68	200 (100x2)	none	36" F.	1 f/ex.	17
2. Hips, exam. (R)		440	880					2.2f/ex.Fem. 2.2f/ex.Male	21
3. Lumbar spineAP(R)	660	225	0	72	100			Normal voltage	16
	250	95	0	120	13			High "	
4. Lumbar spine, AP(R)	5200	227	24	68	200 (100x2)	none	36" F.	1 f/ex.	17
	1000	40	6	120	20 (100x.2)	none	36" F.	High voltage	
5. Lumbar spineAP(R)	4700			58	420	1	36" F. 28.2"S		27
6. Lumbar spine Planigraphy AP(R)	2700			64	210	1	36" F. 28.2"S.		27
7. Lumbar spine AP(R)	1500			55	10 (100x.1)	0.5	36" F		53
8. Lumbar spineAP (R)		Range 20 to 160 Aver. 50	Range 4 to9.5 Aver. 5.						21
		7.6to13						High voltage and/or/heavy filtration	
9. Lumbar spineAP(R)	380			90	40 (100x.4)	3	100cmF. 74cmS.	w.o.b.s.	25
10. Lumbar spineAP(R)	4300			70	160	none	36"F 71 cmS	w.o.b.s. calcd.from Clark(83)	25
11. Lumbar spineAP(R)	8000			66	200	none	30" F 55cmS	w.o.b.s. calcd.from Sante(84)	25

Table 25 Cont'd.

(1) Type	(2) Skin or Air Dose, mr.	(3) Gonad Dose, mr. Female	(4) Male	(5) Voltage KVP	(6) Milliamp. seconds (ma-sec.)	(7) Filter mmAl	(8) Distance	(9) Comments	(10) Ref.
D. Pelvic region (cont'd.)									
12. Lumbar spine, lat. right side up (R)	800	80-left 480-right	0	78	200			Normal voltage	16
	500	10-left 500-right	0	120	70			Higher voltage	
13. Lumbar spine, Lat(R)	12,400	86	26.6	72	500 (200x2.5)	none	36" F	1 f/ex.	17
	4,800	16	7	120	60 (200x.3)	none	36" F.	Higher voltage	
14. Lumbar spine, Lat. (R)	13,500			70	450	1	36" F 25" S		27
15. Lumbar spine, lat. L-5/S-1 (R)	26,000			82	780	1	36" F 23.8" S.		27
16. Lumbar spine, oblique (R)	7,300			64	480	1	36"F 26.6" S		27
17. Lumbar spine, Planigraphy Lat. (R)	5,500			73	210	1	36" F 23.4" S		27
18. Lumbar spine, exam (R)		calcd. 8.0r to center of abdomen						5 films 1 AP, 1Lat. 1Lat. L-5S-1 2 obliques	27
19. Lumbar spine, exam(R)		calcd. 5.0r to center of abdomen						3 films	69
20. Lumbar spine, Lat(R)	5,700			78	5 (50x.1)	0.5	36" F		53
21. Lumbar spine, Lat(R)		Range 60 to 300 Av. 150	Range 20 to 36 Aver. 28						21
		20						High voltage and/or heavy filtration	
22. Lumbar spine, Lat. (R)	1000			90	80 (100x.8)	3	100cmF 66 cm S	w.o.b.s.	25

Table 25 Cont'd.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Type	Skin or Air Dose, mr.	Gonad Dose,mr. Female	Male	Voltage K VP	Milliamp. Seconds (maxsecl)	Filter mmAl	Distance	Comments	Ref.
D. Pelvic region (cont'd.)									
23.Lumbar spine,Lat. L-5,S-1(R)	2,700			90	200 (100x2)	3	100cmF 63cmS	w.o.b.s.	25
24.Lumbar spine,Lat.(R)	14,000			85	320	none	36" F 63cmS	w.o.b.s. calcd.from Clark(83)	25
25.Lumbar spine,Lat. L-5,S-1(R)	17,000			85	360	none	36" F 60cmS	same as no.24	25
26.Lumbar spine,Lat.(R)	16,000			83	200	none	30" F 46cm S	w.o.b.s. calcd.from Sante(84)	25
27.Lumbo-sacral joint,AP(R)	3,900	220	22	80	300 (100x3)	none	36" F	1 f/ex	17
	1,000			120				Higher voltage	
28.Lumbo-sacral joint Rt.Lat.(R)	2,050	0-left 600-right	0	120	100				16
29.Lumbosacral joint AP (R)	6700		4500			none			55
	4200	-	-			1			
	2200		1000			2			
Lat. (R)	20800		2000			none			
	16400		-			1			
	8800		700			2			
Lat.spot(R)	40200					none			
	21500					1			
	14000					2			
30.Lumbo-sacral joint Lat. (R)	8800	800	15	120	350 (200x1.75)	none	36" F	1 f/ex.	17
	17000			80					
31.Lumbosacral joint,exam(R)		1025	81					4.1 f/ex.Fem. 2.7 f/ex.Male	21
32.Pelvis,AP(R)		500	200	550	66	100		Normal volt.	16
		350	155	350	120	16		High voltage	

Table 25 Cont'd.

(1) Type	(2) Skin or Air Dose, mr.	(3) Gonad Dose, mr. Female	(4) Male	(5) Voltage KVP	(6) Milliamp. seconds (maxsec)	(7) Filter mmAl	(8) Distance	(9) Comments	(10) Ref.
D, Pelvic region (cont'd.)									
33. Pelvis, AP (R)	4700	210	1100	65	100 (200x.5)	none	36" F.	1 f/ex.	17
34. Pelvis, AP(R)	5300	600		58	420	1	36" F 28.2"S	Dose calculated at 10 cm depth	27
35. Pelvis		Range 50 to 700 Aver. 300	Range 140 to 2600 Aver. 600						21
		20-170					High voltage and or/ heavy filtration		
36. Pelvis+ sacrum AP (R)	320			75	50 (100x.5)	3	100cm F. 74 cm S	w.o.b.s.	25
37. Pelvis AP (R)	2600			70	100	none	36" F 71cm S	w.o.b.s. calcd. from Clark (83)	25
38. Pelvis+ sacrum AP(R)	3600			63	100	none	30" F	w.o.b.s. calcd. from Sante(84)	25
39. Pelvis-sacrum, Lat (R)	21000	2800		74	750	1	36" F 23.8"S	Dose calcd. at 10cm depth	27
40. Pelvis Lat. (R)		Range 1400 to 1700 Av. 1600							21
		220-1500					High voltage and/or heavy filtration		
41. Pelvis exam (R)		800	1080					1.6f/ex. Fem. 1.8f/ex. male	21
42. Pelvis (R)	1100			60	10 (100x.1)	0.5	36"F		53
43. Pelvis(R)	1300					2		1 f/ex.	55
44. Pelvis+ sacrum, Lat. (R)	3000			85	250 (100x2.5)	3	100cmF 63cmS	w.o.b.s.	25

Table 25 Cont'd.

(1) Type	(2) Skin or Air Dose, mr.	(3) Gonad Dose, mr. Female	(4) Male	(5) Voltage KVP	(6) Milliamp. seconds. (maxsec)	(7) Filter mmAl	(8) Distance	(9) Comments	(10) Ref.
D. Pelvic region (cont'd.)									
45. Pelvis Lat. (R)	22000			86	480	none	36" F 60 cm	w.o.b.s. calcd. from Clark(83)	25
46. Sacroiliac AP (R)	360	155	50	120	20				16
47. Sacroiliac	4000	180	57	63	200	none (100x2)	36" F	1 f/ex.	17
48. Sacroiliac PA (R)		Range 84 to 152 Aver. 90							21
49. Sacroiliac Lat. (R)		Range 300 to 4100 Aver. 500	30						21
50. Thigh and Knee, AP (R)	2800			55	300	1	36" F. 29" S		27
51. Thigh + Knee, Lat. (R)	2100			55	240	1	36" F 29" S		27
52. Thigh exam (R)							2 films 1AP+1Lat. Dose calcd. to center of thigh-500 mr.		27

Table 25 Cont'd.

(1) Type	(2) Skin or Air Dose mr.	(3) Gonad Dose, mr. Female	(4) Male	(5) Voltage KVP	(6) Milliamp. seconds (maxsec.)	(7) Filter mmAl	(8) Distance	(9) Comments	(10) Ref.
E. Chest region, including Upper Spine									
1.Chest	15	0	0	62	13				16
PA (R)	30	0	0	120	0.7			High voltage	
2.Chest(R)									
PA	160	0.07	0.36	68	300AT	none	72" F		17
Lateral	420	0.07	0.36	68	300AT	"	72" F		
Tomograph	360	0.7	6.2	62	50(25x2)	"	48"F		
MM		0.15	0.25	83	24(300 x0.08)	"	36" F		
3.Chest (R)									
PA	60			59	24	1	72" F		27
Lateral	120			78	24	1	72" F		
oblique	70			63	24	1	72" F		
PA(Bucky)	220			64	36	1	50" F		
Lat(Bucky)	430			77	36	1	50" F		
Exam							2PA,1BuckyPA, 1 Lat.Center of chest dose=100(calcd)		
4.ChestPA(R)	50			72	20 (200x.1)	0.5	72" F	14"x17"	53
5.Chest (R)		Range 0.3 to 8.9 Aver. 2	Range 0.07 to 1.6 Aver. 0.3						21
		0.12-0.6					High voltage and/or heavy filtration		
Exam (R)		2.4	0.4					1.2f/exFem. 1.3f/exmale	
6.Chest (R)									
Lat.	13			90	6(100x.06)	3	72"F	w.o.b.s.	25
PA	6			90	3(300x.01)	3	72" F	"	
tomos.AP	40			90	4(5x.8)	3	100cm.F.	"	
" lat.	200			90	16(20x.8)	3	100cm.F	"	
7ChestPA(R)	31					2			55
Lat(R)	400					2			
8.Chest									
Exam(R)	190				55	1	72"F	1AP+1Lat.	71
	500				150	1	40" F	1 Bucky AP +1Bucky Lat.	
9.Chest,PA (F)	3r/min			85	4ma				72

Tabl 25 Cont'd.

(1) Type	(2) Skin or Air Dose mr.	(3) Gonad Dose,mr. Female	(4) Male	(5) Voltage KVP	(6) Milliamp. Second (maxsec.)	(7) Filter mmAl	(8) Distance	(9) Comments	(10) Ref.
E. Chest region (Cont'd.)									
10.Chest(F)									
Old machine	30-120r			88	180-720 (3x60-240)		25cm S		56
New machine	15-60r			70-84	180-720 (3x60-240)		38 cm S		
11.Heart,exam									28
a.Chest(R)	.13-.32r .04-.12r						72" F 72" F	1 regularfilm or 1 fast "	
b.Barium meal(F)	7.7r			60	315(1.5 x210)		80cm F		
" (R)	0.6-1.9							1 film	
c.Catheterization(F)	110r			64	600(0.5 x12000)		40 cm.S	Field at skin =12x12cm	
(R)	1r							1 film	
d.Angiocardiography(R)	15r			77.5	40(400 x0.1)			10 films	
Total	136r								
12.Heart Catheterization(F)	36-60r			83	2880-4800(4 x12-20min)	3			72
13.Myelography(F)	55.7r			88	2210(4.5 x8.2min)				72
14.Ribs AP(R)	2500	0.16	0.48	65	100(200 x0.5)	none	36" F	1 f/ex	17
15.Ribs,exam. (R)		3.8	0.7					1.9 f/ex.Fem 2.3 f/ex.male	21
16.Ribs(1-8) PA(R)	7			70	6(100x.06)	3	72" F	w.o.b.s.	25
17.Ribs oblique	50			85	3(50x.06)	3	48" F	w.olb.s.	25
18.Ribs(1-8) AP(R)	360			72	8	none	30" F	w.o.b.s.calc from Clark(83)	25

Table 25 Cont'd.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Type	Skin or Air Dose mr.	Gonad Dose, mr. Female	Male	Voltage KVP	Milliamp. seconds (maxsec)	Filter mmAl	Distance	Comment	Ref.
E. Chest region (cont'd.)									
19. Ribs oblique (R)	1000			70	16	none	30" F	w.o.b.s. FromClark(83)	25
20. Shoulder AP(R)	1300	0.03	0.22	58	50 (100x0.5)	none	36" F	1 f/ex.	17
21. Shoulders, Exam (R)		3.4	0.7					1.7f/exFem. 2.2f/ex.Male	21
22. Shoulder, AP(R)	65			60	25 (100x.25)	3	39 1/2"F	w.o.b.s.	25
23. Shoulder AP(R)	410			55	25	none	36" F	w.o.b.s. calcd.from Clark(83)	25
24. Shoulder AP (R)	1000			54	50	none	30" F	w.o.b.s. calcd.from Sante(84)	25
25. Angiocardiography, PA Exam (R)	range 3.3 to 6.8r Aver. 4.6r			70-95	2 (20x 0.1)		48" F.	10 f/ex. Field 24.6"diam. (large cone) 18.3"diam. (small cone)	70
26. Cervical spine, AP(R)	1500	0.06	0.27	58	100 (100x1)	none	36" F	1 f/ex.	17
Lat(R)	1100	0.20	0.92	70	150 (100x1.5)	none	60" F	2 f/ex	
27. Cervical spine AP(R)	1200			54	150	1	36" F		27
Lat (R)	400			64	150	1	72" F		
28. Cervical spine exam (R)		1.2	1.5					2.3 f/exFem. 2.9 f/exMale	21
29. Cervical spine Lat(R)	25			90	10 (100x.1)	3	72" F	w.o.b.s.	25
30. Cervical spine Lat.(R)	700			65	80	none	60" F	w.o.b.s. Calcd.from Clark(83)	25
31. Cervical spine Lat.(R)	1560			60	200	none	60" F	w.o.b.s. calcd. from Sante(84)	25

Table 25 Cont'd.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Type	Skin or Air Dose mr.	Gpnad Dose, mr		Voltage KVP	Milliamp. Seconds (maxsec.)	Filter mmAl	Distance	Comments	Ref.
		Female	Male						
E. Chest region (cont'd.)									
32. Dorsal spine AP (R)	4700	11	8	62	200 (100x2)	none	36" F	1 f/ex.	17
Lat.(R)	10500	2.1	13	68	200 (100x2)	none	36" F	1 f/ex.	
33. Dorsal spine									
AP(R)	4500			58	390	1	36" F		27
Lat(R)	4000			70	180	1	36" F		
Lat(R)	6000			58	480	1	40" F		
Planigraphy AP(R)	2700			64	210	1	36" F		
" Lat(R)	1800			65	105	1	36" F		
34. Dorsal spine exam(R)		124	17.2					2.1f/exFem. 2.3f/exMale	21

Table 25 Cont'd.

(1) Type	(2) Skin or Air Dose mr.	(3) Gonad Dose, mr Female	(4) Male	(5) Voltage KVP	(6) Milliamp. Seconds maxsec.	(7) Filter mmAl	(8) Distance	(9) Comments	(10) Ref.
F. Head examinations									
1. Head (R)								Pituitary Dose calc mr.	27
a. AP	5400			69	330	1	36" F	900 at 9cm	
b. PA	4100			62	300	1	36" F	500 at 11cm	
c. submento-vertex	7200			69	420	1	36" F	800 at 11cm	
d. Lateral	2800			60	270	1	36" F	500 at 8 cm	
Planigraphy(R)									
e. AP	2700			65	210	1	36" F		
f. PA	2700			65	210	1	36" F		
g. Lateral	2300			60	210	1	36" F		
Sinuses(R)									
h.frontal	3400			62	270	1	36" F	400 at 11cm	
i.Maxillary	4300			65	315	1	36" F	800 at 10cm	
j.Lateral	800			54	90	1	36" F	100 at 8cm	
k.Oblique	2500			54	270	1	36" F	300 at 9cm	
Mastoids(R)									
l.Bullitt	1400			56	150	1	36" F	200 at 8cm	
m.Stenvers	3200			62	270	1	36" F	500 at 9cm	
n.Skull exam(R)								7 exposures 3 Lat+1AP+2PA+1Hirtz Dose at center of head=4000	
o.Encephalogram exam (R)								14 exposures 8 Lat.films+2AP+4PA Dose at center of head calcd. =8000	
2.Skull,exam (R)								7 exposures center of head dose =1000	69
3.Skull,exam (R)	2300				200	1	36" S	1 AP+1Lat.	71
	4600				400	1	36" S	3 AP+2Lat.	
4.a.Skull (R)	4000	0.05	0.2	65	125 (100x1.25)	none	36" F	4 f/ex.	17
b.Sinuses (R)	4000	0.05	0.2	80	100 (100x1)	none	30" F	4 f/ex	
c.Mastoid (R)	4000	0.05	0.2	70	100 (100x1)	none	30" F	4f/ex	

Table 25 Cont'd.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Type	Skin or Air Dose mr.	Gonad Dose, mr Female	Male	Voltage KVP	Milliamp. Seconds (maxsec)	Filter mmAl	Distance	Comments	Ref.
F. Head examinations (cont'd.)									
5.Skull									
a. PA(R)	1300			54	150 (100x1.5)	0.5	36" F		53
b. Lat.(R)	1300			54	150 (150x1.5)	0.5	36" F		
6.a.Skull(R)		Range 0.013 to0.4 Aver. 0.3	Range 0.036 to0.96 Aver. 0.06						21
b.Skull exam(R)		1	0.2					3.3f/exFem. 3.4f/exMale	
7.Sinuses(R)									
a. OM	960			85	40 (100x.4)	3	70cmF	w.o.b.s.	25
b. O.F.	660			85	30 (100x.3)	3	70cmF	"	
c. Lat.	260			75	10 (100x.1)	3	70cmF	"	
8.Sinuses(R)									
a. OM	3000			75	60	none	30" F	w.o.b.s.	25
b. OF	2400			67	60	"	30" F	calcd.from	
c. Lat.	720			60	24	"	30" F	Clark (83)	
d. Oblique	2000			67	50	"	30" F		
9.Sinuses (R)									
a. OM	5000			76	100	none	30" F	w.o.b.s.	25
b. OF	5000			77	100	"	30" F	calcd.from	
c. Lateral	3300			67	100	"	30" F	Sante (84)	
10.Cerebral angiography exam(R)	8400 6400 14800			75-85	33-40 (200x1/6 to 1/5) per film			8 AP 8 Lateral. Field 14" or 9 1/2" diameter	72

Table 25 Cont'd.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Type	Skin or Air Dose mr.	Gonad Dose,mr Female	Male	Voltage KVP	Milliamp. seconds (maxsec.)	Filter mmAl	Distance	Comments	Ref.
G. Extremities									
1. Ankle, AP and Lat.(R)	170			70	35 (20x1.75)	3	30" F	w.o.b.s.	25
2. AnkleAP(R)	1700			60	70	none	30" F	w.o.b.s.	25
Lat(R)	1440			60	60	"	30" F	calcd.from Clark(83)	
3. Ankle AP(R)	1000			55	50	none	30" F	w.o.b.s.	25
Lat(R)	850			50	50	"	30" F	calcd.from Sante(84)	
4.Extremities (R)	250			50	25 (50x.5)	0.5	36" F		53
	1000			45	100 (50x2)	0.5	36" F		
5.Extremities exam (R)		1	2.1					2.1f/exFem. 2.1f/exMale	21
6.Fingers wrist and elbow(R)	440	0.026	0.13	58	25 (100x.25)	none	36" F	2f/ex.	17
7.Foot and ankle(R)	440	0.012	0.62	62	25 (100x.25)	none	36" F	2 f/ex.	17
8.Hands (R) PA	84			50	40 (100x.4)	3	30" F	w.o.b.s.	25
oblique	140			50	60 (100x.6)	3	30" F	"	25
9.Hands (R) PA	380			60	20	none	30" F	w.o.b.s.	25
oblique	640			60	30	"	30" F	calcd.from Clark'83)	
10.Knee(R) AP	37			82	6 (50x.12)	3	100 cmF 82 cm S	w.o.b.s.	25
Lat.	28			75	"	3	100 cmF 84 cmS	"	
11.Knee (R) AP	220			60	10	none	36" F 79 cmS	w.o.b.s.	25
Lat.	130			60	8	"	36" F 81cmS	calc.from Clark(83)	

Table 25 Cont'd.

(1) Type	(2) Skin or Air Dose mr.	(3) Gonad Dose, mr. Female	(4) Male	(5) Voltage KVP	(6) Milliamp. Seconds (maxsec.)	(7) Filter mmAl	(8) Distance	(9) Comments	(10) Ref.
G. Extremities (cont'd.)									
12. Knee (R)	970			51	50	none	30" F 64cmS	w.o.b.s. calc.from	25
Lat.	850			49	50	none	30" F 66cmS	Sante (84)	
13. Knee, Tibia and Fibia (R)	440	0.55	13	67	50 (100x.5)	none	36" F	2 f/ex.	17
14. Lower leg and ankle (R)									
AP	300			46	50	1	36" F		27
Lat.	300			46	50	1	36" F		

Table 25 Cont'd.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Type	Skin or Air Dose mr.	Gonad Dose, mr		Voltage KVP	Milliamp. seconds (maxsec)	Filter mmAl	Distance	Comments	Ref.
		Female	Male						
H. Examinations of Children								Age, years	
1. Abdomen (R)									
AP-KUB	160		150	60	20			0-2	16
"	310	130	310	50	50			2-7	
"	600	240	250	58	75			7-11	
2. Chest (R)									
AP	23	0	2	45	10			0-2	16
AP		0	0	45	10			2-7	
AP		0	0	45	10			7-11	
3. Lumbar Spine (R)									
AP	420	190	420	60	50			0-2	16
Lateral	800	300	900	66	80			0-2	
"	1300	500	1200	70	120			2-7	
"	1800	730	300	74	160			7-11	
4. Pelvis or Hips (R)	160	90	160	60	20			0-2	16
	280	140	280	46	50			2-7	
	730	300	700	76	50			7-11	
5. Skull (R)									
Basal View	180	1	1	65	25			0-2	16
		0	0	65	25			2-7	
		0	0	65	25			7-11	

Table 25 Cont'd.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Type	Skin or Air Dose, mr.	Gonad Dose, mr Female	Fetal	Voltage KVP	Milliamp. Seconds (maxsec.)	Filter mmAl	Distance	Comment	Ref.
J. Obstetrical Examinations (Pelvimetry unless otherwise noted; all are radiography)									
1. Obl., AP	2[illegible],000	240		120	200 (200x1)	none	36" F.		17
2. Obl.,Lat.	12,400	840		120	100 (200x.5)	none	36" F		17
3. Abdomen, Obstetric	2,600	260		80	150 (200x.75)	none	36" F		17
4. Abdomen Obstetric	1,250			120				High voltage	17
5. AP	5,000	400	400	65	300	1	36" F 25.8" S	Doses calc. Ovaries 13 cm Fetus 13 cm	27
6. Lateral	26,700	3500	1300	78	780	1	36" F 22.6"S	Doses calcd. Ovaries 11cm Fetus 16 cm	27
7. Superior-inferior inlet	14,000	400	900	75	420	1	36"F 22.6"S	Doses calcd. Ovaries20cm. Fetus15cm	27
8. Pregnancy		Range: 180-3500 Av.1500	Range: 400-6000						21
9. Pregnancy Vertex Presentation			Range: 2000-30000					Dose is to male gonads of fetus	21
10. Pregnancy		30		100				High volt. and/or heavy filtration	21
11. Examination		2100-2900						4 f/ex.	57
12.a. AP supine		a+b=		70	100(40x2.5)		37" F	4f/ex(a+b+c+d).Patient at 14 wks. maturity.	41
b. Sub-pubic Sitting		390		82	140 (40x3.5)		30" F		
c. Superior-inferior sitting		c+d=4700		92	320 (40x8)		37" F		

Table 25 Cont'd.

(1) Type	(2) Skin or Air Dose mr.	(3) Gonad Dose, mr Female	(4) Gonad Dose, mr Fetal	(5) Voltage KVP	(6) Milliamp. seconds (maxsec)	(7) Filter mmAl	(8) Distance	(9) Comments	(10) Ref.
J. Obstetrical Examinations (cont'd.)									
12.d. Lateral, erect		Total exam. =860		92	200 (40x5)		37" F		
13.a. AP supine		Total Exam, a+b+c+d = 80		77	100 (40x2.5)		37" F.	Patient at 37 weeks maturity compare with no. 12	
b. Sub-pubic sitting				85	140 (40x3.5)		30" F.		
c. Superior-inferior sitting				100	320 (40x8)		37" F.		41
d. Lateral erect				88	240 (40x6)		37" F.		
14.a. Lateral			1200					3 f/ex. Dose is at fetal head.	
b. Inlet			400						
c. Outlet			400						58
Total exam.			2000						
15. Lateral	120 r		6000	80	400 (50x8)		91 cm F. 24 cm S	Fetal gonads 15 cm.deep	59
16. Oblique, AP	50 r		3000	80	400 (50x8)		82 cm F 41 cm S	Fetal gonads 15 cm deep	59
17. Vertex Presentation male fetus									
a. Lateral	120 r		30000	80	400 (50x8)		see 15.	Fetal gonads 8 cm deep	
b. Oblique, AP	50 r		15000	80	400		see 16	7 cm deep	59
18. Lateral	8-20 r	230-1300	400-1000	84	400-750		22"-29"S		60
19. Oblique AP	16-30 r	230-1300	1000-1800	84	600-1200		22"-28" S		60
20. Vertex presentation, male Fetus								Other data same as in Nos. 18 and 19	60
a. Lateral			2000-5000						
b. Oblique AP			5000-9000						
21.a. AP Supine frontal.			100	75-95	150-500	0.5		3 films per exam	
b. Lateral abdomen.			200-300	"	"	0.5			
c. Lateral Projection.			200-300	"	"	0.5			42
22. One view		2000							61

Table 25 Cont'd.

(1) Type	(2) Skin or Air Dose mr.	(3) Gonad Dose, mr Female	(4) Gonad Dose, mr Fetal	(5) Voltage KVP	(6) Milliamp. seconds (maxsec)	(7) Filter mmAl	(8) Distance	(9) Comment	(10) Ref.
J. Obstetrical Examinations (cont'd.)									
23. Exam.		7000						5 films/ex.	61
24. Exam.			2500-3000						33
25.								Routine exam. during first half of pregnancy.	
Lateral	36,500	3,700		82	400			1 f/ex.	43
AP	8,400*	1,400*		82	40			2 f/ex.	
AP,45°	1,400	200		82	60			1 f/ex.	
Exam.	46,300	8,300						4 f/ex.	
* Dose is for 2 films									
26.								Routine exam. during 2nd half of pregnancy.	
Lateral	40,000	4,200		85	450			1 f/ex.	
AP	14,000*	3,000*		85	100			2 f/ex.	42
AP,45°	1,500	300		85	60			1 f/ex.	
Exam.	55,500	7,500						4 f/ex	
* Dose is for 2 films								compare with No. 25	
27. Lateral	9000			78	300	0.5			53
28. AP	3600			67	250	0.5			53
29. AP			1700	82	120	2.5	72 cm S.	Dose to male Fetal gonads, 5 cm depth (late pregnancy)	85
30. Lateral			7700	82	375	2.5	66 cm. S	Dose to male fetal gonads, 5 cm depth. (late pregnancy)	85

K. Dental X-Ray Examinations

Note: Direct gonad doses reported only in No. I-1. See comments and also Table 38 for related data.

I. Short cone technique (7"-9" target-film distance)

(1) View	(2) Skin Dose R/Film	(3) KVP	(4) MAS	(5) Filter mmAl	(6) Films Per Exam	(7) Comments	(8) Ref.
1.a. Full mouth, aver.	33	65	10	none	14	Gonad dose per film for a, b, and c reported as 0.06 mr. to female and 0.34 mr. to male. Skin dose in a. is reported as per film but is probably per exam.	17
b. Bite wing	8	65	40	"	1		
c. Auxiliary	2.5	65	10	"	1		
2.a. Upper molar	14	65	80	1.9			27
b. " premolar	10	65	60	1.9			
c. " incisor	11	65	65	1.9			
d. Lower molar	12	65	70	1.9			
e. " premolar	9	65	50	1.9			
f. " incisor	10	65	60	1.9			
3. Full mouth, aver.	4.4	65	29	0.5 (inherent)	14	Eastman Kodak radiatized film used. Dose range in 40 patients 2.4-6.5 r/f.	51
4.a. Full mouth, aver.	12.6	45	28	none	25	Machine B	49
b. " " "	8.5	65	27	"	28	Machine C	
c. " " "	2.6	45	28	2		Machine B	
d. " " exam.	35				about 25	In the 10 patients d. through m. the total dose applies to the area of the mouth which is overlapped in all the films.	
e. " " "	65						
f. " " "	115						
g. " " "	135						
h. " " "	280						
i. " " "	282						
j. " " "	285						
k. " " "	285						
l. " " "	315						
m. " " "	315						
5.a. Full mouth, aver.	8.72	65	50	none	19	Medium speed film	46
b. " " "	3.38	65	50	1	19	" " "	
6.a. Lower molar	16.2	60	40	none		DuPont 551 film	50
b. " "	7.3	60	18	"		" " 550 "	
c. " "	7.6	60	40	2		" " 551 "	
d. " "	3.54	60	18	2		" " 550 "	

Table 25 Cont'd.

K. Dental X-Ray Examinations (Cont'd.)

I. Short cone technique (Cont'd.)

(1) View	(2) Skin Dose R/Film	(3) KVP	(4) MAS	(5) Filter mmAl	(6) Films Per Exam	(7) Comments	(8) Ref.
6.e. Lower molar	3.9	75	20	2		DuPont551 film	
f. " "	1.95	75	10	2		" " 550 "	
g. " "	1.22	100	4	2		" " 551 "	
h. " "	0.61	100	2	2		Entries a.-h. are taken from a larger table in (50) to show effects of filter and film speed. See also no.II-1.	
7.a. Full mouth, aver.	151-235 r/min. Aver.175 r/min.		For all cases a.thru g. average time=3.5 sec.Aver. current = 10ma.			Manufacturer A, 7 machines	48
b. " " "	72-156 r/min. Aver.154 r/min.					Mfr.B, 4 machines	
c. " " "	58-102 r/min. Aver.80 r/min.					Mfr.C, 4 machines	
d. " " "	96 r/min.					Mfr.D, 1 machine	
e. " " "	91 r/min.					Mfr.E, 1 "	
f. " " "	294 r/min.					Mfr.E, 1 "	
g. " " "	267 r/min.					Mfr.F, 1 "	
II. Long cone technique (14"-16" Target - Film Distance)							
1.a. Lower molar	0.92	60	12	none		DuPont Film 555	50
b. " "	0.46	60	12	2		" " " "	
c. " "	2.27	75	8	2		" " " "	
d. " "	0.07	100	1.34	2		" " " "	
e. " "	0.08	100	2	3		" " " "	
						Taken from a larger table in (50) to show effects of varying filter and film. Entry d. gave lowest dose. See also No.I-6.	
2. Full mouth, aver.	3.8	65	30	none	30		49
3.a. Full mouth, aver.	2.18	65	75	none	19	Fast film used	46
b. " " "	1.23	70	75	1	19	" " "	
4.a. Full mouth, aver.	42-79 r/min. Aver.46		Average time per film=3.5 sec., aver. current=10ma.			Mfr. A, 2 machines	48
b. " " "	31 r/min.					Mfr.B, 1 machine	
c. " " "	29 r/min.					" C, 1 "	SeeI-7

Table 25 Cont'd.

(1)	(6)	(2)	(3)	(4)	(9)	(10)
Type of Examination	Time, minutes	Skin or Output Dose, Roentg.	Gonad Dose Female Roentgens	Male	Comments	Ref.
L. Summary of Fluoroscopic Examinations						
1. Hysterosalpingography	1.25		0.9			63
2. Barium enema (lower GI)	5		2		Dose at center of abdomen. Includes 5 spot films and 2 PA.	27
3. Barium enema(lower GI)	3	7.5	0.020	0.040		17
4. Barium enema(lower GI)		4.9			Includes 2 spots and 2 films.	55
5. Barium enema(lower GI)	2	15				71
6. Barium enema (colon)	2.5	13	0.42 (aver.)		Includes 3.2 spot films and 2.3 large films on aver.	54
7. Colon	1.5-4	50-130	4-15		Calcd.10cm depth	56
8. Barium meal(upper GI)	3	7.5	0.009	0.020		17
9. Upper GI-Stomach	3-8	100-270			Calcd.depth dose at 10 cm -8-30 r.	56
10.Upper GI	5.7		0.2		Includes 7 spots, 4 stomach, 1 abdomen films	54
11.Upper GI-Stomach	10	177				27
12.GI		13.7			Includes 5 films and 6 spots	55
13.Chest	1-4	33-134				56
14.Heart-barium meal	3.5	7.7				28
15.Heart-catheterization	5-20 Aver.-15	34-86				28
16.Heart-catheterization	12-20	36-60				72
17.Myelography	8.2	56				72
18.General	Per min.	3-28				72
19. "	" "	16.8				53
20. "	" "	23 Aver. Up to 118			General Practitioners - 119 machines	23
21. "	" "	3				26
22.General - pediatrics	" "	3.2-77.7 Aver.23			39 machines	23
23. " "	" "	6-38	1.2-7		7 machines	24
24. " "	" "		0.9-16.5			21
25. " "	Per exam		0.25			29

Table 26

The Population of the United States According to Age and Sex, in 1954 (7)

	Total	Male	Percent	Female	Percent
Total	162,414,000	80,696,000	49.7%	81,718,000	50.3%
Population under 30 years	81,696,000	41,384,000	50.5	40,312,000	49.5%
Percentage of total under 30	50.3%	51.1%		49.4%	
Population under 12 years	40,112,000	20,481,000	51.0%	19,631,000	49.0%
Percentage of total under 12	24.7%	25.3%		24.0%	
Population between 12 and 30	41,584,000	20,903,000		20,681,000	
Percentage of total	25.6	25.8		25.4	
Total in 1949	149,215,000				

Rate of increase of total population between 1950 and 1955 has averaged 2.7 million per year.

Table 27

Data for Calculating the Minimum Annual Genetically Effective Medical Diagnostic X-Ray Dose to the Gonads of the Population in the United States

(See Notes at End of Table)

(1)	(2)	(3)	(4)	(5)	(6)
Type and Number of Examinations	Gonad Dose Per Exam. Milliroentgens Female	Male	Percent of Exams in Group	Total Roentgens Per Year, Female	Male
I. Radiography (Radiologists and all physicians)					
A. Adults (age 12-30) 4.4 million exams - female 4.9 " " male					
1.Genito-urinary tract					
a. Pyelography and urinary tract	200	(100)	6.7	59,000	33,000
b. Salpingography	600	--	0.3	6,600	--
2.Gastrointestinal tract					
a. Abdomen and colon	465	0	12.	245,000	0
b. Stomach and gall bladder	75	0	16.	53,000	0
3.Skeleton-pelvic region					
a. Pelvis and hips	600	1,650	4.2	110,000	340,000
b. Thigh	(300)	(1,650)	(1)	13,000	81,000
c. Lumbar spine and lumbo-sacral joint	800	0	(3)	105,000)	0
d. Sacroiliac	465	150	1.3	27,000	95,000
4.Estremities, chest and head	0	0	55	0	0
Total radiography - adults				619,000	549,000
B. Children Age 0-2 years 0.53 million exams - female 0.60 " " male Age 2-7 years 1.0 million exams - female 1.1 " " male Age 7-11 years 0.64 million exams - female 0.73 " " male					
1. Abdomen			15		
Age 0-2	(240)	450		19,000	40,000
Age 2-7	390	930		59,000	153,000
Age 7-11	720	750		69,000	82,000
2. Pelvis and hips			(19)		
Age 0-2	270	480		27,000	55,000
Age 2-7	420	840		80,000	175,000
Age 7-11	900	2,100		110,000	291,000

Table 27 Cont'd

(1) Type and Number of Examinations	(2) Gonad Dose/Exam Milliroentgens Female	(3) Male	(4) Percent of Exams in Group	(5) Total Number of Roentgens Per Year Female	(6) Male
I. Radiography (Radiologists and all physicians)(cont'd.)					
B. Children (cont'd.)					
3. Lumbar Spine			(3)		
Age 0-2	900	2700		14,000	49,000
Age 2-7	1050	2400		32,000	79,000
Age 7-11	2190	900		42,000	20,000
4. Chest and Head	0	0	63	0	0
Total radiography - children				452,000	944,000
Total radiography				1,071,000	1,493,000
II. Fluoroscopy					
A. Radiologists					
1. Adults 0.73 million exams-female 0.82 million exams-male					
a. Genito-urinary region	500	500	2	7,300	8,200
b. Lower GI	(W) 420	0	40	123,000	0
c. Upper GI	(W) 200	0	48	70,000	0
d. Heart	0	0	10	0	0
Total fluoroscopy, radiol., adults				200,000	8,200
2. Children (all ages) 0.35 million exams-female 0.40 million exams-male					
a. Genito-urinary region	500	500	2	3,500	4,000
b. Lower GI	420	420	40	59,000	67,000
c. Upper GI	200	200	48	34,000	38,000
d. Heart	0	0	10	0	0
Total fluoroscopy, radiol., children				97,000	109,000
B. Non-radiologist physicians					
1. Adults 0.65 million exams-female 0.72 million exams-male					
a. Genito-urinary region	500	500	7	23,000	25,000
b. Gastrointestinal tract	300	0	27	53,000	0
c. Pelvic region	600	1650	15	58,000	18,000
d. Other regions	0	0	51	0	0
Total fluor., non-radiol., adults				134,000	43,000

Table 27, Cont'd.)

(1)	(2)	(3)	(4)	(5)	(6)
Type and Number of Examinations	Gonad Dose/Exam. Milliroentgens		Percent of Exams in Group	Total No. of Roentgens per Year	
	Female	Male		Female	Male
II. Fluoroscopy (Cont'd.)					
B. Non-radiologist physicians (Cont'd.)					
2. Children (all ages)					
0.36 million exams - female 0.41 million exams - male					
a. Abdomen	400	400	15	22,000	25,000
b. Pelvis	600	1,650	22	48,000	150,000
c. Other regions	0	0	63	0	0
Total fluor., non-radiol., children				70,000	175,000
Total fluoroscopy				501,000	335,000
III. Photofluorograms by radiologists					
0.5 million films - female 0.6 million films- male					
Dose per film	3	1	100	1,500	600
IV. Chiropodists and Chiropractors					
A. Radiography					
0.15 million exams - female 0.16 million exams - male					
1. Pelvic region	600	1,650	10	9,000	26,000
B. Fluoroscopy					
0.16 million exams - female 0.18 million exams - male					
1. Pelvic region	600	1,650	10	10,000	30,000
Total chiropodists and chiropractors				19,000	56,000
V. Mass Chest X-Rays					
3.3 million films - female 2.7 million films - male					
Dose per film	3	1	100	9,900	2,700

Table 27 Cont'd.

(1) Type and Number of Examinations	(2) Gonad Dose/Exam. Milliroentgens	(3)	(4) Percent of Exams in Group	(5) Total No. of Roentgens/Year	(6)
	Female	Male		Female	Male
VI. Dental X-Rays					
A. Adults					
44.6 million films-female 27.9 " " male					
Dose per film	0.6	1	100	27,000	28,000
B. Children					
5.6 million films-female 5.4 " " male					
Dose per film	1.8	3	100	10,000	16,000
Total Dental X-Rays				37,000	44,000
VII. Obstetrical Examinations					
A. Mothers					
0.3 million effective pelvimetries	700	-	100	210,000	--
2.5 million effective births for					
a. Placentography (1 film per exam)	155	-	0.6	2,400	--
b. Abdomen flat plate	155	-	3.4	13,000	--
c. Chest (1 film/exam)	0	-	47.4	0	--
Total obstetrical-mothers				225,000	--
B. Fetus					
3.6 million births in hospitals (50% male, 50% female).					
1. Pelvimetry	700	700	11.4	96,000*	96,000
2. Abdomen	200	200	3.4	8,000	8,000
3. Placentography	200	200	0.6	1,300	1,300
4. Chest	0	0	47.4	0	0
Total Obstetrical - fetus				105,000	105,000
Total obstetrical				330,000	105,000
Total Diagnostic Gonad Dose				1,970,000	2,036,000

* All fetus doses have been reallocated to correspond statistically with the other examinations. The multiplying factor is 0.67. See Text, Section 2b.

Table 27

Notes and References for Table 27

Gonad doses are given for one examination unless otherwise specified in Column 1.

Radiographic examinations are based on 3 films per examination.

Gonad doses for radiographic examinations are taken from Billings (16) except for those in parentheses which have been estimated by comparing with neighboring regions or by comparing with the ratio of the gonad doses to the two sexes as given by Martin (21) or Osborn and Smith (22). Gonad doses for fluoroscopy marked with (W) are taken from Weens (54). Female children's doses are assumed the same as female adults in hospitals, and male children the same as female children. Male adults are given zero gonad dose for abdominal fluoroscopy as reported by Billings for radiography. Gonad doses for non-radiologists and chiropodists are taken over or averaged from similar examinations by radiologists. Obstetrical gonad doses are taken from Haas (42) and Martin and Williams (41). Photofluorogram doses are taken from Billings (16) except those in parentheses which are estimated. Mass chest x-rays are assumed the same as photofluorograms by radiologists. Dental x-ray film doses for adults are taken from Stanford and Vance (17) and are estimated for children.

Table 28

Summary of the Genetically Effective Average Gonad Doses From Medical Diagnostic X-Ray Exsminations and Radiation Therapy Treatments Received Per Person During One Generation (Thirty Years) by the Population of the United States

	Minimum Gonad Dose, Roentgens	Probable Gonad Dose, Roentgens
I. X-Ray Diagnostic Examinations		
A. Radiography	1.0	1.8
B. Fluoroscopy	0.3	1.5
C. Photofluorograms and Mass Chest X-Rays	0.006	0.006
D. Dental X-Rays	0.03	0.1
E. Obstetrical X-Rays	0.16	0.7
Total Diagnostic Dose	1.5	4.1
II. X-Ray and Radioisotope Therapy Treatments	0.5	0.5
III. Total Gonad Dose	2.0	4.6

Table 29

Summary of Average Skin Doses Received in Radiographic Procedures Used on Adults

Region	Average of Majority	Average of Billings (16) and Ardran (25)
	Dose in milliroentgens per exposure	
Gastro-intestinal tract	2200	275
Lumbar spine	8000	700
Pelvis and hips	13000	1400
Cervical spine	1080	25 (Ardran)
Dorsal spine	5000	-
Genito-urinary (excluding salpingograms)	2600	-
Head	3000	600
Chest	200	50
Extremities	800	70

Table 30

Data for Calculating the Probable Annual Genetically Effective Medical Diagnostic X-Ray Dose to the Gonads of the Population in the United States

(See Notes and References at end of Table)

(1) Type and Number of Examinations	(2) Gonad Dose/Exam. Milliroentgens	(3)	(4) Percent of Exams in Group	(5) Total Number of Roentgens Per Year	(6)
	Female	Male		Female	Male
I. Radiography (Radiologists and all physicians)					
A. Adults (age 12-30)					
4.4 million exams - female					
4.9 " " male					
1. Genito-urinary tract					
a. Pyelography	1200	2000	4.1	215,000	405,000
b. Urinary tract	1000	300	2.6	113,000	38,000
c. Salpingography	1000	--	0.3	130,000	--
2. Gastrointestinal tract					
a. Abdomen and colon	500	200	12	262,000	118,000
b. Stomach and upper GI	300	200	13	170,000	128,000
c. Gall bladder	200	10	3	26,000	150,000
3. Skeleton-pelvic region	1000	2000	10	440,000	980,000
4. Skeleton-extremities and chest	0.5	1.0	12	300	600
5. Chest	0.3	1.2	35	500	2000
6. Head	0.2	0.6	8	70	200
Total radiography - adults				1,357,000	1,687,000
B. Children					
Age 0-2 years					
0.53 million exams - female					
0.60 " " male					
Age 2-7 years					
1.0 million exams - female					
1.1 " " male					
Age 7-11 uears					
0.64 million exams- female					
0.73 " " male					
1. Abdomen			15		
Age 0-2	240	450		19,000	40,000
Age 2-7	390	930		56,000	153,000
Age 7-11	720	750		69,000	82,000
2. Pelvis and hips			19		
Age 0-2	270	480		27,000	55,000
Age 2-7	420	840		77,000	175,000
Age 7-11	900	2100		110,000	290,000
3. Lumbar spine			3		
Age 0-2	900	2700		14,000	49,000
Age 2-7	1050	2400		30,000	79,000
Age 7-11	2190	900		42,000	20,000
4. Chest			27		
Age 0-2	240	450		34,000	73,000
Age 2-11	5	5		2,200	2,500

Sheet 2

Table 30 (Cont'd)

(1) Type and Number of Examinations	(2) Gonad Dose/Exam Milliroentgens Female	(3) Male	(4) Percent of Exams in Group	(5) Total Number of Roentgens Per Year Female	(6) Male
II. Radiography (cont'd.)					
B. Children (cont'd.)					
5. Skull and extremities			36		
Age 0-2	240	450		46,000	97,000
Age 2-11	5	5		3,000	3,300
Total radiography - children				529,000	1,119,000
Total radiography				1,886,000	2,806,000
II. Fluoroscopy					
A. Radiologists					
1. Adults 0.73 million exams-female 0.82 " " male					
a. Genito-urinary region	3000	6000	2	44,000	98,500
b. Lower GI	1500	750	40	438,000	246,000
c. Upper GI	750	500	48	263,000	197,000
d. Heart	15	20	10	1,100	1,600
Total fluor., radiol., adults				746,000	543,000
2. Children (all ages) 0.35 million exams-female 0.40 " " male					
a. Genito-urinary tract	3000	6000	2	21,000	48,000
b. Lower GI	1500	750	40	210,000	120,000
c. Upper GI	750	500	48	126,000	96,000
d. Heart	15	20	10	500	800
Total fluor., radiol., children				358,000	265,000
B. Non-radiologist physicians					
1. Adults 0.65 million exams-female 0.72 " " male					
a. Genito-urinary tract	3000	6000	7	136,000	302,000
b. Lower GI	1500	750	12	107,000	65,000
c. Upper GI	350	500	15	74,000	54,000
d. Skeleton-pelvic region	3000	6000	10	195,000	432,000
e. Skeleton-extremities	5	5	12	390	430
f. Chest	10	10	36	2,300	2,500
g. Head	5	5	8	520	580
Total fluor., non-radiol., adults				515,000	857,000

Table 30 Cont'd.

(1) Type and Number of Examinations	(2) Gonad Dose/Exam. Milliroentgens	(3)	(4) Percent of Exams in Group	(5) Total No. of Roentgens/Year	(6)
	Female	Male		Female	Male
II. Fluoroscopy (Cont'd.)					
B. Non radiologist physicians (Cont'd.)					
2. Children					
Age 0-2					
0.09 million exams - female					
0.10 " " male					
All examinations	1000	2000	100	90,000	200,000
3. Age 2-11					
0.27 million exams - female					
0.31 million exams - male					
a. Genito-urinary tract	1000	2000	7	19,000	43,000
b. Lower GI	1000	2000	12	32,000	75,000
c. Upper GI	500	600	15	20,000	28,000
d. Skeleton-pelvic region	1000	2000	10	27,000	62,000
e. Extremities, chest, head	30	40	56	4,100	6,300
Total fluor., non-radiol., children				192,000	414,000
Total fluoroscopy				1,811,000	2,079,000
III. Photofluorograms by radiologists					
0.5 million films - female					
0.6 million films - male					
Dose per film	3	1	100	1,500	600
IV. Chiropodists and Chiropractors					
A. Radiography					
0.15 million exams-female					
0.16 million exams-male					
1. Pelvic region	1000	2000	10	15,000	32,000
B. Fluoroscopy					
0.16 million exams-female					
0.18 " " male					
1. Pelvic region	1000	2000	10	16,000	36,000
Total chiropodists and chiropractors				31,000	68,000

Table 30 Cont'd.

(1) Type and Number of Examinations	(2) Gonad Dose/Exam, Milliroentgens	(3)	(4) Percent of Exams in Group	(5) Total No. of Roentgens/Year	(6)
	Female	Male		Female	Male
V. Mass Chest X-Rays					
3.3 million films-female 2.7 " " male Dose per film	3	1	100	9,900	2,700
VI. Dental X-Rays					
A. Adults					
44.6 million films-female 2719 " " male Dose per film	2	8	100	8,900	223,000
B. Children (under 10)					
5.6 million films-female 5.4 " " male Dose per film	4	12	100	22,000	65,000
Total Dental X-Rays				110,000	288,000
VII. Obstetrical Examinations					
A. Mothers					
0.3 million effective pelvimetries	2,500	-	100	750,000	--
2.5 million effective births for					
1. Placentography (1 film per exam)	260	-	0.6	3,900	--
2. Abdomen flat plate(1 film)	260		3.4	23,000	--
3. Chest(1 film/exam)	0.1		47.4	100	--
Total obstetrical-mothers				776,000	
B. Fetus					
3.6 million births in hospitals (50% male, 50% female)					
1. Pelvimetry	4000	4000	11.4	546,000*	546,000
2. Abdomen flat plate(1film)	400	400	3.4	16,500	16,500
3. Placentography (1 film)	400	400	0.6	2,900	2,900
4. Chest (1 film)	0.3	0.3	47.4	200	200
Total obstetrical - fetus				566,000	566,000
Total Obstetrical Dose				1,341,600	566,000
Total Diagnostic Gonad Dose				5,200,000	5,800,000

* All fetus doses have been reallocated to correspond statistically with the other examinations. The multiplying factor is 0.67.

Table 30

Notes and References for Table 30

Gonad doses are per examination unless otherwise specified in Column 1.

Radiographic examination doses are based on three films per examination.

Averages of all the gonad doses reported in Table 25 for the particular examination were used wherever possible. In some cases minimum values were used, as in the children's radiographic gonad doses. Many estimates had to be made for gonad doses from examinations performed by non-radiologists because there were no measurements available. Section 2 of the text discusses the origin of the gonad doses used.

Table 31

Birth Statistics (30)

Total Live Births by Year

Year	Number
1946	3410,738
1947	3816,770
1948	3636,627
1949	3648,867
1950	3631,512
1951	3822,961
1952	3913,115
1953	3964,750
1954	4078,055

Live Births by Order of Birth for 1954

Order	Number	Percent of Total
First	1159,644	28.4%
Second	1119,393	
Third	785,066	
Fourth	442,800	
Fifth	234,717	
Sixth and seventh	206,708	
Eight and greater	129,727	
Total	4078,055	
Second and greater	2918,411	71.6%

Number of Live Births by Attendance in 1954

	Number	Percent
Physicians in Hospitals	3759,518	89.7%
Physicians not in Hospitals	118,478	2.8%
Midwife and not specified	139,366	3.3%
Illegitimate	176,600	4.2%
Total	4193,962	100.0

Table 32

Frequency of Obstetrical X-Ray Examinations (Kohl, 31)

	Primipara Patients	Multipara Patients	Overall Average
Number of Patients	26,894	51,947	78,841
Percentage of Patients Given Pelvimetry examinations (3 films average each)	23.3%	5.25%	11.4%
Placentography (1 film)	0.44%	0.64%	0.57%
Abdomen (1 film)	2.6	3.75%	3.4%
Chest	48.3%	47%	47.4%

Table 33

Calculation of Effective Number of Pelvimetries Given Per Year

Child Order	No. of Births, millions per year	Percent in Hospitals	Percent X-Rayed	Percent Expected to Have Another Child	Number X-Rayed Millions
1	1.16	90	23	96.5	0.232
2	1.12	90	5	71	0.036
3	0.79	90	5	56	0.020
4	0.44	90	5	52	0.010
5	0.23	90	5	91	0.009
6th and 7th	0.21	90	5	0	0
Number of effective pelvimetries per year, millions					0.307

Table 34

Minimum and Probable Doses Received by the Fetal Gonads in Obstetrical X-Ray Examinations

Type of Exam.	No. of Exams Per Year	Minimum Dose/Exam. Roentgens	Total Roentgens Per Year	Probable Dose/Exam. Roentgens	Total Roentgens Per Year
Pelvimetry	410,000	0.7	287,000	4	1,640,000
Abdomen	122,000	0.2	24,000	0.4	49,000
Placenta	20,000	0.2	4,000	0.4	8,000
Chest	1,700,000	0	0	0.003	5,100
			315,000		1,702,000
Dose per Child Averaged into 4,000 births (one generation dose), roentgens			0.08		0.42

Table 35

Age and Sex Distributioh in the Mass Chest X-Ray Surveys

I. Allegheny County, Pa. 1953 (65)

Age Group (Years)	No. X-Rayed Male	No. X-Rayed Female	
15-19	186	219	
20-24	100	123	
25-29	156	162	
30-34	157	213	
35-39	207	190	
40 and older	866	921	
Total	1,672	1,828	48% male, 52% female
Percent under 30	26.4	27.5	47% male, 53% female

II. Los Angeles County - 1950 (66)

Age Group	Total X-Rays	
Under 15	25,442	
15-19	184,833	
20-24	155,208	
25-29	208,302	
30-34	204,612	
35-114	362,800	
45 and older	584,467	
Total	1,725,766	47% male, 53% female
Percent under 30	33.2	

III. Mariopa County (Phoenix), Arizona 1952 (67)

Under 15	2,293
15-24	36,855
25-34	37,159
35-44	36,749
45 and older	51,389
Total	164,445
Percent under 30	35%

IV. Total Number of Mass Chest Photofluorograms Taken in the United States (68)

Year	Number*	Percent of Population Examined
1952	13,466,229	8.6%
1953	15,545,875	9.8
1954	16,233,027	10.1

* Reported by State. If add x-rays taken by federal agencies, the total number becomes more than 22 million in 1954.

It is estimated that 2% to 3% of the photofluorograms are followed by a large chest film (14" x 17"). (67).

Table 36A

The Age and Sex Distribution of Patients Receiving Dental Radiograms in the United States in 1950.

Based on a Sample of 3673 Patients

(American Dental Association, 45)

	Percent of all Ages Within Each Sex	
Age Group	Male	Female
Less than 9	7	5
10 - 29	36	40
Total under 30	43%	45%
Percent of all patients	41%	59%

Table 36B

The Number of Dental Radiograms Taken of Patients By Age and Sex in the United States in 1955

(Based on a Total of 189 million Radiograms, and Using Data of Table 36A)

	Millions of Radiograms		
Age Group	Male	Female	Total
Less than 9	5.4	5.6	11
10 - 29	27.9	44.6	72.5
Total under 30	33.3	50.2	83.5

Table 37

Skin Doses Received by Patients in Dental Radiography Outside the Direct Beam and Near the Gonads

A. Budowsky, J. et al (51)

65 KVP, 10 ma, no added filter (0.5 mm Al inherent), short cone (8"), Field size at skin = 4 1/8" diameter, 2.9 sec. average exposure per film.

Dose per film at abdomen: 32 mr. average
0-400mr. range

B. Spear, L. B. (46)

65-70 KVP, 15 ma, 1 mm. Al filter, long cone (15"), 5 sec. average per film.

Location	Dose per exposure mr.
Chest	4.4
Shoulder	3.1
Knee	0.2
Ankle	0.5

C. Jacobson, L. E. and Sheppard, I. M. (52)

Stray radiation in mr/sec. at 3 feet from a phantom and outside direct beam from different machines.

Machine	KV	ma	Output r/min.	Stray mr/sec.
A.	63	10	230	0.47
B	67	11	181	0.42
B	67	11	181	0.55
C	-	10	187	0.58
D	-	-	120	0.88
D	-	-	120	1.18
E	-	10	208	0.70
F*	45	5	135	0.15
GG**	63	10	120	0.055

* Machine F had only a 2 inch diameter field at cheek

** Machine G had a 14 inch long cone; field 3" diameter at cheek Other machines had 7" short cone and field diameter at cheek of 3.5". Machines listed twice are for two different positions.

Table 38

Summary of Abdominal Skin Doses and Direct Gonad Doses in Dental Radiography

Doses in mr per film

Abdominal Skin Dose	Male Gonad Dose	Female Gonad Dose	Source
-	1	0.6	Stanford and Vance (17) See Note (a)
32	-	-	Budowsky et al (51)
1	-	-	Spear, L. B. (46) See Note (b)
4	-	-	Jacobson and Sheppard (52) See Note (c)

a) Calculated for three second exposure.

b) Estimated by interpolation from Table 37.

c) Calculated for three second exposure from average of values given in Table 37. Corrected from 3 feet to 2 feet by inverse square law since 2 feet is the approximate distance from lower abdomen to face in sitting position.

Figures 1 and 2

Depth-Dose Relationships for X-Ray Machines

(Ritter et al, 27)

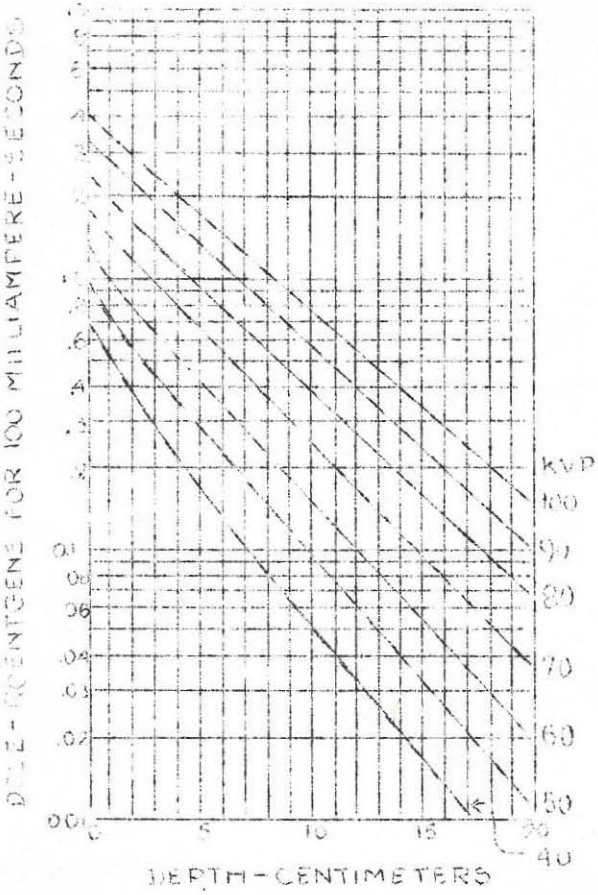

Fig. 1. Skin and depth doses per 100 milliampere-seconds at focal spot-skin distance of 26.4 inches (67 cm.) with 1 mm. of Al added filter.

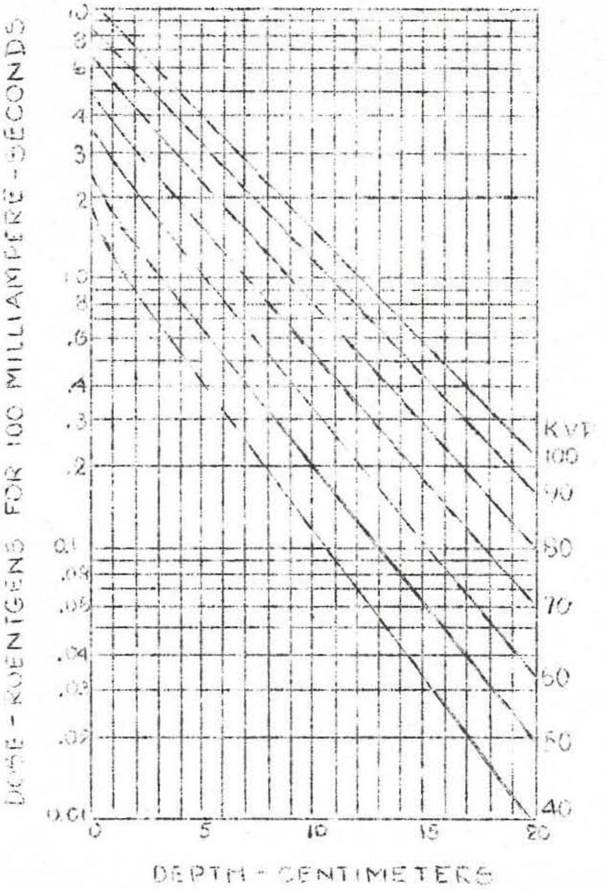

Fig. 2. Skin and depth doses per 100 milliampere-seconds at focal spot-skin distance of 15.8 inches (40 cm.) with 1 mm. of Al added filter.

APPENDIX - A

Calculation of the Number of Hospital Radiographs Taken Per Year Based on United Hospital Fund Data.

The United Hospital Fund (13) has furnished some data for the year 1954 for some fifty voluntary general hospitals in the New York City area. The number of x-ray films taken in the admitted departments (private, semi-private, and ward) and in the outpatient (clinic) departments and private ambulatory service is presented in the Fund Report (13a) together with the number of patients in the various departments (13b). A summary of the data is given in Table A-1. The total number of patients admitted to general hospitals in 1953 was 18,692,812 (14) and this number is estimated to be 20 million in 1955. At 3.3 films per admission (Table A-1) the number of films consumed by this source was 66 million. The nationwide consumption of films in outpatient clinics is estimated to have been 13 million. This was calculated using the data in Tables A-1 and A-2 in the following way. The number of outpatients for the hospitals in the New York City area, corrected to 52 hospitals, per admitted inpatient is found to be 1.02. This ratio must be corrected for the fact that not all hospitals have outpatient departments. From data in Reference 14, the fraction of hospitals with outpatient departments, weighted roughly by the number of admissions, is estimated to be 0.52, as shown in Table A-2. Thus the weighted number of outpatients per inpatient is estimated to be 0.53. Combining this factor with the number of inpatients and the number of films per outpatient (Table A-1) yields the 13 million films. The total number of films consumed in general hospitals is 79 million and considering the number of x-ray examinations performed in other types of special hospitals, such as maternity units, children's hospitals, orthopedic, etc. when weighted by admissions the total number of films is estimated to be about seven percent greater. In addition, many radiologists have their own office practice. In 1946, according to Fef. 2, 17% reported no hospital connection; 60% reported that they had an office practice; 9% owned part or all of the x-ray equipment in the hospital with which they were connected. In 1949, 1300 radiologists, or 36% of the total number owned their own equipment. To take into account the number of films taken by radiologists in their private offices, the number of hospital films should be multiplied by about 1.2. The total number of films taken by radiologists in hospitals or private offices is about 100 million.

Table A-1

Summary of United Hospital Fund of New York for 1954 (13)

In-Patients (Private, Semi-Private, Ward, and Private Ambulatory).
52 Hospitals.

Number of admissions	460,972
Number of x-ray films*	1,520,000
Films per admission	3.3

Outpatients (Clinic)
47 hospitals.

Number of patients	427,791
Number of x-ray films*	508,000
Films per patient	1.19

* The total number of x-ray films has been corrected for differences between the number of hospitals reporting on x-ray films and on admissions, or outpatients.

Table A-2

The Fraction of Outpatient Departments Among The General Hospitals in the United States, Weighted by the Number of Admissions

Data taken from (13)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Hospital Bed Size Range	No.of Admissions to Gen. Hospitals (Millions)	Percent of Total Admissions	No.of Hospitals With Out-Patient Depts	No.of Hospitals	%of Hospitals With Out-Patient Depts.	Weighted Percentage of Hospitals with Out-Patient Depts.(3x6)
Less than 25	0.558	3.0	307	1044	29.4	0.9
25-49	1.606	8.6	546	1581	34.5	3.9
50-99	2.893	15.5	542	1498	36.1	5.6
100-199	4.622	24.7	590	1227	48.1	11.9
200-299	3.353	17.9	323	551	58.5	10.5
300-499	2.989	16.0	281	389	72.2	11.5
More than 500	2.671	14.3	329	4450	59.8	8.6
Total	18.692	100.0	2918	6840		52.0%

F. References

1. Modern Medicine Surveys, August 1949. Market Research Department, Modern Medicine Publications, Inc., 84 South Tenth Street, Minneapolis, Minn. Private Communication from Mr. A. W. Hubbard, Director of Research. Some of this material is given in Donaldson, Ref. 2.

2. Donaldson, S. W., Amer. J. Roentgen. and Radium Therapy 66, 929 (1951).

3. Mt. Sinai Hospital (New York City), Annual Report for 1951.

4. The Society for the New York Hospital, Annual Report for 1955.

5. Survey of General Practitioners in the United States on the Use of X-Ray Equipment, National Electrical Manufacturers Association (NEMA). 155 East 44th Street, New York 17, N. Y., May 1, 1956.

6. Ingraham, S.C. II, Terrill, J.G. Jr., and Moeller, D.C., Radiation Exposure in the United States, X-Rays in the Healing Arts, Unpublished Memo dated April 1953, U. S. Public Health Service, Washington, D. C.

7. The American Medical Directory, 1950 and 1956 Editions.

8. Private communication from Mr. L. E. Barron, X-Ray Sales Supervisor, E. I. Du Pont de Nemours and Co., 248 W. 18 Street, New York 11, N. Y., Sept. 18, 1956.

9. Advance Report - 1954 Census of Manufacturers, May 1956, Series MC-38-2.3, U. S. Department of Commerce, Bureau of the Census, Washington 25, D.C.

10. United States Department of Commerce Memo BD-554, Sept. 22, 1955.

11. Private Communication from Mr. G. R. Struck, Manager, Medical Division, Eastman Kodak Co., Rochester 4, N. Y.

12. United States Public Health Service in cooperation with the American Hospital Association, "Keeping our Hospitals Operating", Public Health Service Publication No. 272, 1953.

13.a. Financial and Statistical Information Relating to Member Hospitals of the United Hospital Fund of New York - Year 1954.

13.b. Sundry Financial and Statistical Information Relating to Hospitals in New York City, Dec. 31, 1954. Prepared by United Hospital Fund of New York. Sent by courtesy of Mr. E. Bauer.

14. Hospital Service in the United States - 1953 Census. From the J.A.M.A. Hospital Number, May 15, 1954. With Supplement.

15. The Biological Effects of Atomic Radiation, National Research Council - National Academy of Sciences Publication, June 1956.

16. Billings, N. S., Norman, A., and Greenfield, M. A. The University of California at Los Angeles School of Medicine Atomic Energy Project. Report UCLA-340, July 22, 1955.

17. Stanford, R. W, and Vance, J., Brit. J. Radiol. 28, 266 (1955).

18. Report on the Use of X-Ray in the Prepaid Medical Care Plan, Trinity Hospital, Little Rock, Arkansas, 1942. Quoted in Modern Medicine Surveys, (see Ref. 1)

19. Hodges, F. J. Public Health Reports 62, 1129 (1947).

20. Department of Radiology, New York Hospital. Data for 1955. Courtesy of Dr. J.A. Evans, Radiologist-in-Chief and Mr. T.E. McFarlan, Executive Assistant for Professional Services of the Hospital. Data also from Ref. 4.

21. Martin, J., Medical Journal of Australia, ii, 806 (1955).

22. Osborn, S.B. and Smith, E.E., Lancet, i, 949 (1956).

23. Sonnenblick, B.P., Journ. Newark Beth Israel Hospital, 6, 31 (1955).

24. Buschke, F. and Parker, H M., J. Pediatrics 21, 524 (1942).

25. Ardran, G. M. and Crooks, W.E., Brit. J. Radiol. 26, 352 (1953).

26. Ardran, G. M., Brit. J. Radiol. 29, 266 (1956).

27. Ritter, V.W., Warren, S. R. and Pendergrass, E. P., Radiology 59, 238 (1952).

28. Hills, T. W., and Stanford, R. W., Brit. Heart J. 12, 45 (1950).

29. Clein, N., J. Pediat. 45, 310 (1954).

30. Vital Statistics - Special Reports, National Summaries 44, 157 (1956). U. S. Dept. of Health, Education, and Welfare, National Office of Vital Statistics.

31. Private Communication from Professor S. G. Kohl, Department of Obstetrics and Gynecology, State University of New York College of Medicine, Brooklyn 3, N. Y. Compiling of data performed by Mr. H. R. Schechter.

32. Barter, R. W. and Parks, J., South. Med. J. 46, 555 (1953).

33. Coe, F. M., South. Med. J. 48, 609 (1955).

34. Dell, J. M., South. Med. J. 48, 604 (1955).

35. Jacobs, J. G., Am. J. Obst. and Gyhec. 65, 897, (1953).

36. Marck, A. and Melamed, A., Am. J. Obst. and Gynec. 67, 564 (1954).

37. Schneider, M., Texas State M. J. 43, 758 (1948).

38. Swenson, P. C., M. Clin. North Amer. 32, 1659 (1948).

39. Thoms, W. and Wyalt, R. W., Am. J. Obst. and Gynec. 59, 424 (1950).

40. Walsh, J. W. et al, Am. J. Obst. and Gynec. 68, 674 (1954).

41. Martin, J. M. and Williams, E. R., Brit. J. Radiol. 19, 297 (1946).

42. Haas, R. L., Latourett, W. B. and Whitehouse, W. M., Surg. Gyn. Obst. 99, 462 (1954).

43. Moloy and Swenson, "The Use of the Roentgen Ray in Obstetrics", Chapter in Vol. II of Diagnostic Radiology, edited by R. Golden, 1945.

44. Van Allen, W. W., Public Health Reports 65, 865 (1950).

45. Nineteen Fifty Survey of the Dental Profession, Parts 6 and 7, J. Amer. Dental Assoc. 42, 196 and 444 (1951).

46. Spear, L. B., J. Amer. Dental Assoc. 51, 7 (1955).

47. Nineteen Fifty Three Survey of Dental Practice, Part 7, J. Amer. Dental Assoc. 49, 221 (1954).

48. Todd, R.R. and Worth, D. C. J. Amer. Dental Assoc., 51, 664 (1955).

49. Nolan, W. E., J. Amer. Dental Assoc. 47, 681 (1953) and Radiology 61, 625 (1953) (with Patterson, W. W.).

50. Etter, L.E., Amer. Dental Assoc. 53, 305 (1956).

51. Budowsky, J. et al, J. Amer. Dental Assoc. 52, 555 (1956).

52. Jacobson, L. E. and Sheppard, I. M., N. Y. State Dental Journal 18, 367 (1952).

53. Handloser; J. S. and Love, R.A., Brookhaven National Laboratory Report AECU-1177, 6/29/51. Also in Radiology 57, 252 (1952).

54. Weens, H. S., Clements, M.D. and Tolan, J.W. Radiology 62, 745 (1954).

55. Kirsh, I.E., J.A.M.A. 158, 1420 (1955).

56. Bell, A.L.L., Radiology 40, 139, (1943).

57. Sonnenblick, B. P., Talk before the Atomic Energy in Industry Forum, New York City, Oct. 26, 1955. Sponsored by the National Industrial Conference Board, Inc.

58. Berman, R., "Obstetrical Roentgenology" (Book) (1955).

59. Osborn, S.B., Brit. J. Radiol. 24, 174 (1951).

60. Stanford, R.W., Brit. J. Radiol. 24, 226, (1951).

61. Greenhill, J. P. "Obstetrics" (Book) (1955).

62. Report on an Institute Meeting, Brit. J. Radiol. 25, 387 (1952).

63. Barnett, E. and Bewley, D.K., J. Fac. Radiologists 6, 186 (1955). Abstracted in Radiology 65, 819, (1955).

64. World Almanac for 1956, New York World Telegram and Sun.

65. Participation in the Allegheny County, Pa. Mass Chest X-Ray Campaign of 1953, Public Health Reports 70, 669 (1955).

66. Drolet, G.J., Tuberculosis Control Foundation, Los Angeles, May 1953.

67. Statistical Report, Mariopa County Chest X-Ray Survey, Inc. Phoenix, Arizona, Oct. 1952.

68. Reported Tuberculosis Data - Calendar Year 1954, Public Health Service Publication No. 471, Jan. 1956, U.S. Dept. of Health. Note: References 66, 67 and 68 were kindly furnished by Dr. A. Lowell, Statistician with the New York Tuberculosis Association.

69. Moore, R. C., Radiology 57, 250 (1952).

70. Dubilier, W. et al, Am. J. Roentgenol. and Rad. Therapy 70, 441 (1953).

71. Poppel, M. W. Sorrentino, J. and Jacobson, W.G., J.A.M.A. 147, 630 (1951).

72. Jacobson, L.E. et al, Radiology 58, 568 (1952).

73. Clark, S.W., Bulletin Atomic Scientists 12, 14 (1956).

74. Kaplan, I.I., Proceedings of the First World Congress on Fertility, Vol. I, P. 409 (1953) with discussion by C. Mazer (P.430).

75. Rakoff, A.E., Proceedings of the First World Congress on Fertility, Vol. I, P. 433 (1953).

76. Drips, D.G., Amer. Journ. Obst. and Gynec. 55, 789 (1948).

77. Israel, S.C., Amer. Journ. Obst. and Gynec. 64, 971 (1952).

78. Williams, W.W., Am. J. Roentgen. 69, 88 (1953) with comments by D. J. Roberts.

79. Roland, M. and Weinberg A., Amer. Journ. Obst. and Gynec. 62, 1167 (1951).

80. Kaplan, I.I., J. Obst. and Gynec. of the Brit. Empire 57, 767 (1950).

81. Kaplan, I.I., Amer. Journ. Obst. and Gynec. 67, 484 (1954).

82. J.A.M.A. 157, 874 (1955).

83. Clark, K.C., "Positioning in Radiography", 5th Ed. 1949. (Wm. Heinemann Ltd., London). Doses calculated by Ardran and Crookes (25).

84. Sante, L.R., "Manual of Roentgenol. Tech., 15th Ed. revised., 1949 (Edward Brothers, Inc., Ann Arbor). Doses calculated by Ardran and Crookes (25).

85. Hol, R. and Koren, K., Acta Radiol., 44, 471 (1955).